POSTFORMAL THOUGHT AND CREATIVITY IN DESIGN PROCESS

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfilment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in Architecture

by
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December 2017
İZMİR

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ACKNOWLEDGEMENTS

I would never have been able to finish my thesis without the guidance of my committee members, the participation of the students, support from my family, and help from friends.

It is with great pleasure that I thank my advisor, Assoc. Prof. Dr Şeniz Çıkış for her help, guidance, support, and caring throughout my research and studies. I have been extremely lucky to have her as my supervisor.

I would love to express my gratitude to Dr Özgü Özkan and Assoc. Prof. Dr Ebru Yılmaz, for guiding my research for the past several years with endless patience, and support.

Thanks to Assoc. Prof. Dr Hikmet Gökmen, Assist. Prof. Dr Onur Orkan AKŞİT and Assoc. Prof. Dr Ahenk YILMAZ for agreeing to be part of the committee, for their encouraging words and for their constructive criticism.

And my family… I am greatly indebted to them for all they have done for me, and I am grateful for their endless love and unconditional support throughout my life. Their selfless sacrifices have enabled me to have the opportunities that have made me who I am today.

Finally, I want to thank myself. Despite the countless sleepless nights, stressful days, and lack of nutrition, my brain and body manage to keep working. Well done guys!

ABSTRACT

POSTFORMAL THOUGHT AND CREATIVITY IN DESIGN PROCESS

The aim of this study is to reveal relations between creativity in design and cognitive development levels of designers with a Post-Piagetian approach. In this study design processes were deeply inspected with the aim of obtaining more comprehensive information about the effects of individual's cognitive status on the design processes, problem-solving and idea generation quality. In this field, studies done so far have been conducted on test results as indicators of creativity. In this study, however, protocol analyses were also evaluated in addition to testing the results, and thanks to this addition, it was possible to determine the qualitative and quantitative effects of the cognitive development levels on creativity.

Total twenty-five students voluntarily participated in the research. To collect data, two different methods were employed. Social Paradigm Belief Inventory (SPBI), was employed to determine students' cognitive stages and scores, and Think-aloud protocol, was used to elicit verbal reports of thought sequences of students. In order to analyse verbal reports for investigating designers' cognitive activities, Linkography method was conducted and general statistics of segments were measured. To exposure, the relations between creativity in design and cognitive development levels of designers, SPBI scores and obtained general statistical values of design sessions were correlated and findings showed that there is a strong and significant correlation between cognitive development levels and creativity in favour of dialectical thinking. Addition to this, participants' partial protocols were analysed syntactically, and the networks were inspected to reveal the impacts of postformal thinking on creative design process with the help of Function-Behaviour-Structure (FBS) Ontology. The findings of the syntactic analysis also supported the finding of the correlations.

Keywords: Design Cognition, Design Process, Postformal Thinking, Creativity, Formal Thinking, Dialectical Thinking, Relativistic Thinking

ÖZET

TASARIM SÜRECİNDE POST- FORMEL DÜŞÜNCE VE YARATICILIK

Bu çalışmanın amacı Post-Piagetian bir yaklaşımla tasarımda yaratıcılık ile tasarımcıların bilişsel gelişim düzeyleri arasındaki ilişkiyi ortaya çıkarmaktır. Kişilerin bilişsel düzeylerinin tasarım süreci, problem çözme ve fikir geliştirme kaliteleri üzerindeki etkileri hakkında daha kapsamlı bilgi edinebilmek adına tasarım süreçleri detaylı şekilde incelenmiştir. Konuyla ilgili olarak bu güne kadar yapılan çalışmalar sadece test sonuçlarına dayanmaktayken bu çalışmada bilişsel gelişim seviyelerinin yaratıcılık üzerine etkisini nitel ve nicel olarak saptamak adına test sonuçlarının yanı sıra protokol analizden de yararlanılmıştır.

Araştırmaya toplam 25 gönüllü öğrenci kaltılmıştır. Veriler iki farklı yöntemle toplanmıştır. Bunlardan ilki olan Social Paradigm Belief Inventory (SPBI) öğrencilerin bilişsel seviyelerini belirlemede, sesli-düşünme protokolü ise öğrencilerin düşünce dizilerinin sözel raporlarının ortaya çıkarmak için kullanılmıştır. Tasarımcıların bilişsel aktivitelerinin incelenebilmesi için sözel raporlar Linkography yöntemi yardımıyla analiz edilmiş, segmentlerin genel istatistikleri çıkartılmıştır. Tasarımda yaratıcılık ile tasarımcıların bilişsel gelişim düzeyleri arasındaki ilişkiyi ortaya çıkarabilmek adına SPBI sonuçları ile tasarım oturumlarına ait genel istatistiki veriler ilişkilendirilmiştir. Elde edilen sonuçlar dialektik düşünme lehine bilişsel gelişim düzeyleri ve yaratıcılık arasında anlamlı bir korelasyon olduğunu göstermiştir. Katılımcıların kısmi sözel raporları üzerinden Function-Behaviour-Structure (FBS) Ontology yardımıyla yapılan sözdizimsel çözümleme de elde edilen bu istatistiki bulguları destekler niteliktedir.

Anahtar Kelimeler: Tasarımda Biliş, Tasarım Süreci, Postformal Düşünce, Yaratıcılık, Formal Düşünce, Diyalektik Düşünce, Göreceli Düşünce

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CHAPTER 1

INTRODUCTION

1.1. Background of the Study and the Problem Statement

Creativity has always been a major topic of design research, owed to this crucial role in the design and problem-solving process (Mumford et al., 1991; Runco, 1994; Torrance and Presbury, 1984 and Presbury; Torrance, 1988; Wallas, 1928). Therefore, research on creativity and its sub-topics cover an extremely broad array of subjects. One of these research sub-topics focuses on cognition and its influences on creative behaviour and creative potentials. Although there is a countless of definitions of creativity due to the lack of consensus, some researchers (e.g. Kampylis and Valtanen, 2010; Rhodes, 1961) tried to collect the prominent definitions and draw a common definition. By taking into consideration of the determined overlapping and intertwining keywords and acts in the definitions by those researchers, in this thesis creativity definition is accepted as combining, synthesizing and/or bridging of already existing ideas, information and/or knowledge in order to generate novel, useful and appropriate solutions. Arthur Koestler (1964) describes the creative process as connecting previously unrelated matrices of thought and generating new ideas. The individual consciously or unconsciously starts exploring knowledge units to discover how they could be linked to each other and how to map them. This mapping allows for new connections in order to solve a problem. In short, according to this approach, a transformation occurs through linking knowledge units, that are associated with each other, or forming new connections between independent knowledge units (Boden, 1994; Gabora, 2002; Santanen et al, 2002, Ward et al, 1997) and this transformation gives rise to novel applicable solutions (Gabora, 2002; Santanen et al, 2002). This process demands an ability to perceive actual or potential relations between knowledge units and to link them in order to generate ideas.

There have been several attempts to reveal the emergence of creativity in the design process, what affects and/or foster creativity, how designers connect the unrelated matrices of thoughts and generate new ideas, and how it can be traced. These investigations differentiated by stemming different paradigms; creativity as a mysterious event versus a product of a successful bisociation. The first group, also known as romantics, claimed that creativity is untraceable, thus cannot be researched. However, the second group, also known as non-romantics, claimed that because of creative insights are also an outcome of the reasoning process, it can be traceable and hence researchable (Sawyer, 2006). So, if the process is inspected, the phenomenon can be solved. In order to trace creativity, researchers argued when and how creativity occurs during the design process and tried to measure contributions of the design actions to the emergence of creative insights.

Stems from this view two main approaches are formed; non-structuralists and structuralists. Non-structuralists (such as Donald Schön) argued that creative insights are the retrieved good ideas that are applied to the problem in a trial-and-error manner (Finke et al., 1992). On the other hand, structuralists claimed that creative insights are the products of an unconscious restructuring process of the problem space and solution space (Finke et al., 1992). When the restructuring results with an overlap of two spaces, creative insight can be perceived and realised.

Although the structuralists and non-structuralists dissenting in the way of generating creative insights, both agree on the thinking modes play a crucial role. This claim stems from the arguments that there should be a relation between the contents and the cognitive processes. Thus, the creative design process research focuses on the content and the transformation of the content.

Goldschmidt (1990) proposed that any design decision as an act of reasoning transforms the design situation. Ömer Akin and Cem Akin (1996), suggested establishing the importance of creative insight in breaking through fixation and establishing a new frame of reference to generate a novel solution to a problem. Cross (1997a), analysed design protocols of a design team to identify the role of the creative event that occurs during problem-solving processes, and how this creative event bridges problem space and solution space. Remko Van der Lugt (2003), accepted idea quality is an indicator of creativity and claimed that a "well-integrated idea generation is an indicator of the quality of process" (p.1). Similarly, Gabriela Goldschmidt and Dan Tatsa (2005) and Tatsa (2005) have shown that ideas heading to novel solutions tend to have plentiful interconnections.

These concepts originating from different researchers can be seen as pieces of a puzzle; sudden mental insight to break through, bridging problem space and solution space, well-integration of sub-ideas and making plentiful interconnections between design moves; the key to this puzzle would be the cognitive development stages where each is a feature of these stages. As Mark Runco (2004) states, creative development is closely connected to cognitive development. Thus, the main hypothesis of this research is finding a creative solution to a design problem requires advanced, rather than formal thinking skills, which are linked with post-formal thought stages, and creative performance has strong connections with the thinking types of the post-formal process; i.e. relativistic and dialectical.

The post-formal thought is a cognitive stage beyond Jean Piaget's formal operations stage. As the individual's cognition develops, his or her thinking and understanding of the world becomes more abstract and complex, and the holistic thinking ability develops in the late formal thought stages. The formal thought stage, also known as the formal operational stage or hypothetico-deductive stage, is the fourth phase in Piaget's theory and starts between ages 11 to 15 (Piaget, 1958). For most of the adolescents, cognitive development stops at this stage, as they think holistically, logically and abstractly and do not need concrete examples anymore while operating. Here, abstract thinking refers to abstraction as in mathematics, where a concrete reality can be unequivocally represented by a symbol, thus problems can only have one true solution. At the formal thought stage, the individual can only find a solution within a closed system and deal with well-defined problems including controllable, specific variables – which makes it ill-suited for design problems characterized by complex variables, incomplete data, and uncertain outcomes. Thus, formal thinking is better applied to problems involving, scientific, logical, and mathematical thinking than ill-defined design problems. While success in natural sciences is closely correlated with the formal thinking ability (Mwamwenda, 1993; Valanides, 1998), design demands creativity and holistic thinking that characterize the post-formal thought stage (Wu and Chiou, 2008).

Formal thinking is unable to solve design problems effectively, as these are open-ended and difficult to solve in a systematic, logical, and methodical way, formal thinking falls shorts in the context of developmentally-appropriateness. One pioneer in the research on post-formal thinking, Michael Lamport Commons and Francis Asbury Richards (2003) explains: "The term "postformal" has come to refer to various stage characterizations of behaviour that are more complex than those behaviours found in Piaget's last stage -formal operations- and generally seen only in adults." (p.199).

According to Commons et al. (2008), post-formal thought places a greater emphasis on both problem solving and problem finding. According to Donald Schön (1983), the "problem of design problem" (p.129) is finding out what the problem actually is. With Cross's (2008) words; the "mysterious, creative part of designing" (p.40) is the ability to find problems, defining possible solutions and using a particular way of thinking. Indeed, finding the design problem is not enough to solve it, the designer also needs to reframe it in order to solve it. The post-formal thought ability allows the individual to reconceptualise problems from different perspectives. Thus, the individual at the post-formal thinking stage can solve open-ended, complex problems in addition to creating novel relations between knowledge chunks (Commons et al., 2008), and can apply relativistic and/or dialectic thinking to problem-solving.

In relativistic thinking, individuals being aware that the nature of knowledge is not dualistic (Kramer, 1983), the nature of truth is relative (Perry, 1981), and problems can be viewed from many perspectives (Wu and Chiou, 2008). According to Michael Basseches (1984), relativistic thinker assumes that there are multiple subjective realities, thus there cannot be a universal truth. Gisela Labouvie-Vief (1980) points out that autonomous (relativistic) thinkers can take subjective criteria and emotion into consideration while reasoning. As an example (Kramer, 1992), relativistic thinkers accept "there are no absolute moral principles. This is because morality is personal, and people have different ideas about what morality is." (p.1). Thus, relativistic thinkers can create new ideas by linking knowledge units within a dependently changing thought process. This thinking ability can generate more interconnections between ideas than absolute thinking. Schön's rigour vs relevance concept can be applied to our understanding of relativistic thought stage. According to Schön, the dilemma of rigour or relevance arises from the insistence on solving real-life problems in a closed-system by applying technical knowledge obtained from theory-based research and techniques to ill-defined problems (Schön, 1983). But, as is well known, real-life problems can't be easily solved by exclusively applying a 'rational' or 'scientific' approach. Indeed, this kind of insistence is closely related to formal thought. In contrast with the rigorousness of formal thought, relativistic thinking values relevance; it operates in open-systems and allows individuals to think in more complex ways. Thus, according to Pai-Lu Wu and Wen-Bin Chiou (2008), relativistic thinking is a source of greater diversity and novelty.

However, relativistic thinking doesn't allow the individual to link knowledge across multiple perspectives at once. To do this, individual should have the ability to think dialectically. Dialectical thinking is considered the most advanced form of postformal thought (Laske, 2009). According to Basseches (1984), a dialectical thinker is able to apply relativistic and formal logic in a new way by focusing on the process itself. The individuals at the dialectical thought stage are aware of the so-called truth is valid within a specific ideology, but might not be valid in a different reality, thus they apperceive there are multiple 'right' answers. (Labouvie-Vief, 1980). As an example (Kramer, 1992), dialectical thinkers accept “there are non-absolute moral principles. This is because we each form a set of consistent rules to guide our lives, which makes the most sense in terms of our overall life goals” (p.1). By realising there are multiple realities and truths, dialectical thinkers become aware of that all phenomena and their opposites are connected to each other (Kramer, 1989). In dialectic thinking, relativism integrates into the ability to conceptualize contradictions as interrelated and part of a whole. “Reflection for a dialectical thinker is the process of taking one idea, then reflecting upon its opposite or reflecting upon what is left out. The dialectical thinker thus becomes aware of the process of inquiry.” (McBride, 1998, p.22). As for dialectical thinking, as identified in Schön’s dialectic between design and designer, individuals are aware of their thoughts and that the fact that these are in a constant process of evolution (Basseches, 1989). Thus, dialectical thinkers are aware of their ability to break open commons and/or traditions and act more creatively. Dialectical thinkers tend to discuss a problem from different, and even opposite perspectives and find solutions by integrating these into a thesis and anti-thesis. Therefore, dialectical thinking ability may lead to much more interconnections between ideas than formal and relativistic thinking.

1.2. Significance of the Study

As of yet, little research has been focusing on these links between creativity and post-formal thinking stages. In 2008, Wu and Chiou investigated the relationship between post-formal thought levels and creative performance among late adolescents. They employed the Divergent Thinking Test to measure creative performance and the Social Paradigm Belief Inventory to measure participants' thinking levels. The results of their study proved that there is a strong, positive relationship between dialectical and relativistic thinking, and creativity, whereas formal thinking was negatively correlated. Chao-Chin Yang and his colleagues (2010), similarly, examined the connection between the parameters of creativity and dialectical thinking, applying the same method as Wu and Chiou (2008). They also concluded that cognitive development and creativity are closely related and dialectical thinking may be the catalyser of creative performance. Phillippe Blouin and Stuart McKelvie (2012) researched the connection between post-formal thinking with metaphor and irony as predictors of creativity. By employing the Social Paradigm Belief Inventory, and Irony Test and the Divergent Thinking Test, they demonstrated that post-formal thinking scores are good predictors of creativity and are also correlated to the identification and subjective appreciation of metaphor and irony, whereas formal thinking was correlated negatively.

As presented above, all previous research investigated the relationships between creativity and post-formal thinking by the comparing test results. In this research, to acquire a more deepened understanding on the relationships between creativity in design and post-formal thinking, a different approach was adopted; where data was obtained by analysing the design sessions' protocols, and Social Paradigm Belief Inventory results were compared, in order to identify whether or not post-formal thinking levels affect idea generation quality and problem-solving skills in the context of creativity.

1.3. Methodology and Research Questions

The main hypothesis of this research is finding a creative solution to a design problem requires advanced, rather than formal thinking skills, which are linked with post-formal thought stages, and creative performance has strong connections with the thinking types of the post-formal process; i.e. relativistic and dialectical.

The research questions to be answered in this study are as follows:

1. What is the relationship between creativity and cognitive development?

1.1. What is the relationship between formal thinking and creativity?

1.2. What is the relationship between post-formal thinking and creativity?

1.2.1. How the creativity and idea generation productivity differentiate according to post-formal stages?

1.2.2. Do relativistic thinking and/or dialectical thinking foster creativity and idea generation productivity?

In order to answer these questions and to test the hypothesis, a two legs methodical approach which consists quantitative and qualitative parts is applied. The deductive part has a quantitative methodical approach which is also designed as two legs; at the first part, participants’ thinking levels are determined by the help of Social Paradigm Belief Inventory. At the second part, participants’ design processes’ data collected and analysed by the help of Linkography. Later on, the results are compared and a conclusion is drawn. At the inductive part a qualitative methodical approach is adopted, and focused on the syntactic analysis with two purposes; the first purpose is finding answers of the research questions, and the second purpose is the verification of the results of the quantitative methodical part. To do so, after every participants’ critical move thresholds are calculated, and the ones which breed more ideas are determined, the constituent design decisions of the critical moves syntactically analysed. By doing so, the occurrence of creative insights is inspected related to postformal thinking and its role in the design process.

1.4. Brief Outline of the Thesis

This thesis is structured according to provide a better understanding of the relationships between creativity and post-formal thought. To do so, a brief theoretical and methodological background is given in Chapter 1, where the rationale of the research is addressed in detail.

Chapter 2, focuses on the theoretical framework which contains the information and interpretations of a deep literature review on adult cognitive development and cognition in design creativity.

Chapter 3 presents the experimental setting of the research, as well as the two pilot studies and their findings that structured the main empirical study. In this chapter, it is also presented that the detailed information of the Social Paradigm Belief Inventory and Linkography methods.

At Chapter 4, the results are presented and the findings are discussed in detail.

Chapter 5 presents the conclusion of the empirical study and remarks.

CHAPTER 2

THEORETICAL FRAMEWORK

2.1. Adult Cognitive Development

With the developments in technology and daily needs of users, in order to create more effective solutions to more complex design problems the need for more creative and innovative designers has increased. Therefore, the efforts to enhance design professionals' skills and abilities for generating new knowledge to solve problems become one of the main focuses of design science. Generating new knowledge and solving problems are cognitive processes, hence to achieve the goal of educating more creative and innovative designers, cognition and cognitive development should be revisited.

Cognition is defined as "the mental process or faculty by which knowledge is acquired" (The American Heritage Dictionary, 1982) and "understanding through thought, experience, and the senses" (The Oxford Dictionary). The cognitive process allows individuals *knowing, memorizing, perceiving, learning, evaluating, reasoning, problem-solving* and *thinking* (Shaffer, 1985). From the moment an individual is born, she/he starts to perceive her environment to satisfy her/his basic needs to survive. With the age, the needs get more complex and she/he should develop her/his mental capabilities according to the complexity of her/his needs. "C*ognitive development* refers to these changes that occur in individual's mental skills and abilities." (Shaffer, 1985) As cognition is used for generating new knowledge and solving problems, development of cognition helps individuals to generate more complex knowledge to solve more complex problems.

Piaget (1950) states that cognitive development is the main determiner of humans' ways of thinking and understanding the world. He stresses that an individual's horizons are limited with the knowledge available to her/him and how much advanced her/his skills on generating new knowledge from previous ones at that very point (Piaget, 1958). Therefore, as individual's cognition develops her/his thinking, and understanding of the world become more abstract and complex. This acceptance is the origins of Piaget's theory which indicates human cognitive development go through four stages and it is dependent on age as well as education. In this chapter where the first three stages were briefly reviewed, fourth stage and post-formal stages were introduced in depth.

2.1.1. Piaget's Theory

Piagetian theory based upon the idea of cognitive development is a gradual process occurs by interacting with their environment starting from childhood to adulthood (Partington, 1997). According to Piaget (1958), to organize knowledge, children create *schemes.* These *schemes* help children to create a higher-order system to deal with cognitive conflicts whenever they acquire a new knowledge. Starting with behavioural schemes such as sucking and grasping, as infants get older, they are getting able to create more complex mental schemes for solving more complex problems (Santrock, 2011). Thus, to solve design problems which are always complex, ill-defined and polyhedral, designers need to have complex mental schemes and operate within a higher-order system.

Piaget (1958) explains the core of cognitive development with three fundamental concepts; assimilation, accommodation, and equilibration. As the most important principle, adaption is a continuous process of adjustment to the environment by learning (Singer and Revenson 1996). According to Piaget (1952), adaptation and learning ensue by assimilation and accommodation mechanisms. Assimilation is the mechanism which allows individual to modify newly gained knowledge to fit into the previous schemas and with accommodation mechanism individual change this newly gained knowledge into a new material (Sutherland 1999) to meet the demands of the tasks. "The child assimilates and accommodates, adjusting old schemes, developing new schemes, and organizing and reorganizing the old and new schemes. Eventually, the organization is fundamentally different from the old organization; it is a new way of thinking." (Santrock, 2011, p.88)

According to Peter Sutherland (1999), assimilation and accommodation occur simultaneously and it creates equilibrium. When an individual gains a new knowledge she/he cannot fit into existing schemas by assimilation, a disequilibrium occurs, and the individual seeks to restore balance by accommodation (Shaffer, 1985). Therefore, equilibrium is the shift from a stage to a higher one (Piaget, 1952). Raymond Wlodkowski (1985) carried a research on Piaget's (1950) argument on there might be some dynamics that may motivate an individual to employ equilibrium, and he found games and creative problems are the motivational factors. So, solving design problems may force individuals to equilibration, and may lead them to reach a higher level.

Thus, it can be inferred that creative design process, as being based upon generating new ideas (Koestler, 1964), is not independent of assimilation and accommodation mechanism. Yet, it should not be forgotten that the level of successfulness of the creative design process is not only dependent on a number of generated ideas but also the quality of these ideas (Amabile 1996, Sternberg and Luvart 1999). So, it can be said that assimilation and accommodation mechanism are the foundations of the creative process, but not solely determiners of creativity.

In adulthood, although the old schemes become more fixed and difficult to modify, individuals still can create new schemes and link them to the older ones, which allows her/him to continue learning (Sönmez, 2001). Yet, to understand this process, early childhood intellectual change, Piaget's stages of cognitive development, should be revisited.

Beginning from birth to 2 years old, infants experience sensorimotor stage. During this initial phase of development, infants acquire knowledge by their sensory perceptions and motor activities such as touching, seeing and hearing. The main goal of infants at this phase is to gain knowledge about their environment and being planful problem solvers after going through six sub-stages (Shaffer, 1985).

The *preoperational stage* is the second stage of Piaget's theory and continuous between ages 2 to 7. Piaget calls this period as preoperational because although children gain skills on how to construct and use mental symbols, and symbolic reasoning (Shaffer, 1985) they are not capable to reverse mental actions, but only physical actions (Santrock, 2011). Piaget (1960) rationalizes his claim by pointing out that children's incapability of distinguishing logico-arithmetical operations from spatiotemporal operations.

The 3rd stage of Piaget's cognitive developmental theory, *concrete operational stage* begins at around 7 years old and lasts until 11 years old. According to Piaget, "the concrete operator is finally able to construct accurate mental representations of a complex series of actions." (Shaffer, 1985, p. 352) In this stage, the most critical skills children gained are performing concrete operations and reasoning logically (Inhelder and Piaget, 1958). “The concrete thinker, according to Piaget, is a logical and systematic thinker who can transcend misleading appearances by coordinating multiple aspects of a situation.” (Moshman, 2011, p. 8) The importance of performing concrete operations is being able to reverse and modify internal mental schema (Santrock, 2011). By acquiring this skill, children gain *addition* and *subtraction* concepts and masters in simple deductive reasoning (Shaffer, 1985). In other words, children can understand if 2+5 equals to x, x-2 will equal to 5. Yet, in this stage, children are still limited to the concrete world and cannot apply the skill on hypothetical propositions basis on abstraction. That is the reason Piaget call this period as *concrete operational.*

Formal thought stage, also known as formal operational stage and hypothetico-deductive stage, is the fourth and last stage of Piaget’s theory and starts at the age between 11 and 15. This stage is also known as the beginning of the complex cognitive functioning. The main characteristics of this stage are the developments on logical thought, abstract reasoning, symbolic reasoning, high conceptual thought, being multi-perspective, generalizations and category building (Hatfield and Hatfield, 1992). According to Piaget (1972), the formal operational stage is the peak point of cognitive advancement, and he describes it as a system of operations that are based on the coordination of relations among previous relations.

At this stage, individuals start to perceive as a whole, logically reason by abstract thinking and do not need concrete examples anymore. Here, abstract thinking refers to abstraction in mathematics, the concrete is represented by a symbol and the symbol can refer only one concrete, in the same way, problems have only one true solution. At formal thought stage, individual needs to create a solution from a closed system, and can deal with only well-defined problems that need controllable, specific variables. According to Bryan Lawson (1980, p.106), “rigid impositions of closed systems (…) [are] seen by many designers as a treat to their creative role.” Thus, formal thinking may only suit the problems that call for scientific thinking and logical-mathematical analyses and may not be successfully applied to design problems.

The fore and the most important difference between formal operational thought and former thought stages is the separation of thought from reality, and in addition to this, during the formulation of hypotheses synthetic possibilities can be envisioned to be tested against reality (Sutherland, 1999; Moshmaan 2011; Riegel, 1973). Edwin Arthur Peel (1972) states that a formal thinker is also able to predict outcomes. The process of solving design problems also demands coordination of relations among previous relations, formulation of hypothesis based upon synthetic possibilities, and predicting the possible outcomes (Schön, 1983; Cross, 2001). Therefore, it can be said that a formal thinker is capable to solve design problems, yet it does not mean the solution will be satisfactory in the context of creativity and idea generation quality since the thinker has to work in a closed system.

Piaget (1972) calls formal thought stage is also second-order operations, and according to him one of the most significant achievements of the formal operational stage is the capacity to generate second-order concepts and relationships. The difference between first order operations and second order operations lies in the understanding of reality. First-order concepts are seen during the concrete operational stage and are the direct extensions of reality. Yet, second-order concepts are derived from an evaluated reality, and from "the realization of a particular possibility" (Moshman, 2011, p.8) which are still based on real world. Hugh Rosen (1985) states that to think at this level individual must be capable of integrating abstract concepts in a complex way. So, the process itself highlights the success rather than the output. David Moshman and Bridget Franks (1986) gives the example below to explain it:

Elephants are bigger than mice.
Dogs are bigger than mice
Therefore, Elephants are bigger than dogs.

Mice are bigger than dogs.
Dogs are bigger than elephants.
Therefore, mice are bigger than elephants.

As seen above, even if the second premise is contradictory with the real world, a formal thinker sees the logic behind it and accepts its validity. To recognize the second premise as valid in the context of logic, formal thinker applies hypothetico-deductive reasoning. The hypothetico-deductive reasoning is "being able to distinguish logic from the truth, […] enables one to consider the logical implications of a set of premises whether or not one accepts those premises." (Moshman, 2011, p.10) However, in the formal thought stage, premises are valued as either true or false (Commons and Richards, 2002). In other words, two contradictory premises cannot be both true and one of them must be accepted as false. This raises objections by pointing out that formal thinking disallows integration, rather demands domination of one (Broughton, 1977; 1984). This problem arises because of dominant thinking type in formal thought stage, called as absolute thinking. Absolute thinking allows individual to think according to absolute principles, which are based on the acceptance the world is stable and fixed (Chiou, 2008). “During absolute thought, ideas are seen as accepted and predictable, contradiction is seen as distressing, and change occurs through outside forces (Kramer, Kahlbaugh, and Goldston, 1992).” (as cited in Vanier and Searight, 2013, p. 50) Yet, in the designing process, there is no true or false, but there are values such as effective or ineffective, adequate or inadequate, useful or useless. Also in design contradictions are welcomed and accepted as challenges which enrich the success of output.

Besides focusing only on the process and ignoring the output quality, and lack of integration, another limitation of the formal thinking is the lack on falsification strategy (Moshman, 2011). Hence, these limitations raised serious criticism on whether all adults operate in formal thought stage, and researchers claimed that most of the adults do not operate at formal thinking level (Ehindero, 1979; Martorano, 1977; Mwamwenda, 1993; Roberge and Flexer, 1979; Schwebel, 1975), as well as there are higher thinking levels than formal thought stage (Rosen, 1985; Kahlbaugh and Kramer, 1995; Kramer et al., 1992, Commons et al, 1998; Commons and Richards 2003).

While success in natural sciences is closely connected to formal thought stage, design demands such as creativity and thinking as a whole are closely connected to higher thinking capabilities than formal thought stage. Therefore, determining whether post-formal thought stage meets designing demands is crucial.

2.1.2. Post-Piaget and Post-formal Thinking

The contemporary research on adult cognitive development formed on John Dewey’s and Piaget’s developmental theories. As Piaget’s theory grounded on a Cartesian-Newtonian approach and hypothetico-deductive system of reasoning and ends at 15 years old, researchers (e.g. Commons and Ross, 2008; Kohlberg, 1975; Kramer, 1983; Lave, 1988; Sinnott, 1984; Walkerdine, 1988) argued that there must be a developmental stage beyond Piagetian formality, and they tried to formulate a post-Piagetian cognitive theory.

Commons (2008) published his theory *Hierarchical Complexity* based on Lawrence Kohlberg's (1963) studies on moral judgements. According to Commons's model, Post-formal thought stage has four sub-stages. First sub-stage is Systematic Stage that enables to solve multivariate problems. At this sub-stage, individuals can determine relations among variables and possible multivariate causes. Systematic Stage enables to determining possible multivariate outcomes that may be determined by many causes; the building of multivariate representations of information in the form of tables, matrices, diagrams, or narrative; multidimensional ordering of possibilities, including the acts of preference and prioritization.

Second sub-stage is Metasystematic Stage which 1 to 2 percent of people in the U.S. population function without [educational] support. At this cognitive level, individuals can compare, contrast, transform, and synthesize prescribed systems. This ability also means that individual become aware of the similarities, differences and constituent causal relations of systems. Commons and Linda Marie Bresette (2008) posit that "a person must function in the area of innovation at least at the Metasystematic stage of hierarchal complexity to produce truly creative innovations." (p. 507).

At third sub-stage; Paradigmatic stage, individuals gain the ability to bring out new paradigms from metasystems. To create a new paradigm, an individual can able to recognize similar patterns in metasystems and generalizing from one to other, an incomplete metasystem that appears unrelated to the original field. According to Commons and Sara Nora Ross (2008), less than .05 percent of people in the U.S. population function at Paradigmatic stage without educational support.

The fourth and last sub-stage is Cross-Paradigmatic Stage. At this cognitive level, individuals gain the ability to integrate paradigms and set new disciplines. For example, analytical geometry, chaos theory, particle physics and quantum mechanics are products of cross-paradigmatic acts (Commons and Ross, 2008).

Although Common's *Hierarchical Complexity* is the most comprehensive and aligned study with Piaget's theory, critics have claimed that such models do not take into account the intermediate variables of the personality, self, context, history, or social life; instead, they rely too heavily on purely abstract systems, limited in their applicability to different domains of adult life (Labouvie-Vief and Diehl, 2000; Sinnott, 1998)" (Kallio, 2011, p. 795)

The first researcher who presented a new viewpoint on adult cognition based on epistemic understanding, which takes intermediate variables of the personality, self, context, history, or social life into account was William Perry (1981). He claimed that adults' reasoning progress through three stages:

1. Dualism: Same as with Piaget's Formal thinking stage, where truths are absolute.
2. Relativism: Accepting that there are different viewpoints
3. Commitment: Synthesising a subjective conclusion from different, and even contradictory viewpoints

In 1983, Deirdre Kramer published her adult cognitive development model. Her model includes also three phases, like as Perry's, yet with different titles:

1. Absolute thinking: Same as with Piaget's Formal thinking stage and Perry's dualism
2. Relativistic thinking
3. Dialectical thinking

In the following, this study focus on the Kramer's model (1983) as his Social Paradigm Belief Inventory (SPBI) is used to determine cognitive stages and scores.

2.1.2.1. Relativistic Thinking

Kramer (1983) posits relativistic thinking one of the core thinking types of post-formal reasoning, as it allows to realize of relativistic nature of truth and knowledge. Thus, relativistic thinkers are aware of change and independence of beliefs. Bärbel Inhelder and Piaget (1958) define relativity "as the coordination of two or more frames or systems of reference." (Yan and Arlin, 1995)

According to Kramer (1983), the shift toward to post-formal thinking starts with this realization, and relativistic thinking is the first step of the process. According to Labouvie-Vief and Diehl (2000), the shift happens when the young adult needs to use of a higher level reflection and subjective knowledge integration, such as solving an ill-defined real-life problem by using tacit knowledge acquired by subjective experiences. In some cases, adult finds herself/himself in a contradiction with the so-called absolute truths imposed externally, and so conflicts can arise. Hence, to solve the problem, an adult should detach herself/himself from imposed beliefs and become autonomous

(Labouvie-Vief and Diehl, 2000) and a self-referential thinker (Sinnott, 1998). According to Jan Sinnott (1998) becoming a self-referential thinker allows individual “to order lower level formal truth and logic systems” (p. 34) subjectively while knowing that the order is not absolute. Yet, although the relativistic thinker knows there is other truth systems, she/he can operate in one system:

> For example, the knower may be aware that both Euclidean and non-Euclidean geometries exist and that each has contradictory things to say about parallel lines. (…) A mathematician bent on knowing reality must decide at a given point which system he or she intends to use, and must make a commitment to that system, working within it, knowing all along that the order system is equally valid, though perhaps not equally valid in this particular context. The selected geometry system then does become the mathematician’s true description of the world. (Sinnott, 1998, p. 25)

As seen in the Sinnott’s example, for a relativistic thinker consistency lies at one of the logical systems chosen according to relevance to the problem. This ability allows individuals to aware of personal preferences, beliefs, values, world-views, and life experiences are differentiated among people, and understand complex relationships while socially interact and/or dealing ill-defined problems. By doing so, individuals can create a shared reality with others (Sinnott, 1998). According to Kramer (1983), Stephen Pepper’s (1942) Contextualism is the foundation of this feature of relativistic thinking. In contextualism, the truth criterion is the idea’s/solution’s success at a given point (Fox, 2006). Thus, there are many ways approach any phenomenon, which leads the individual to divergent production and creativity (Kramer, 1983).

2.1.2.2. Dialectical Thinking

Piaget (1958) defines contradiction as the functional disequilibrium. Any new knowledge which doesn’t fit the concurrent schemata causes a disequilibrium. When a non-dialectical thinker gains a new knowledge she/he cannot fit into existing schemas by assimilation and accommodation, a disequilibrium occurs, and the individual might seek to restore balance by creating new schemata or regretting the new knowledge entirely. However, a dialectical thinker tends to convert the new contradictory knowledge into a new material, by synthesizing of the thesis and antithesis. Thus, Klaus Rigel (1973) posits dialectical thinking as the last stage of adult cognitive development. According to Riegel (1973, p. 350) “dialectical conceptualization characterizes the origin of thought in the individual and in society (…) and represents a necessary synthesis in the development of thought toward maturity" and for dialectical thinkers "[the] contradictions [are] basic property of thought and creativity" (p.366).

> The mature person needs to achieve a new apprehension and an effective use of contradictions in operations and thoughts. Contradictions should no longer be regarded as deficiencies that have to be straightened out by formal thinking but, in a confirmative manner, as the very basis of all activities. (Riegel, 1975, p. 101)

According to Basseches (1984), dialectical thinking is the ability to find and creating order, which is why dialectical thinkers are better at finding problems as well as solving them. Basseches (1980, p.404) explains dialectical perspective as:

> From the dialectical perspective, what might otherwise be viewed as fundamental elements of existence are instead viewed as temporary form which existence takes, and what might otherwise be viewed as interactions of fundamental elements are instead viewed as fundamental process of change through which these forms of existence emerge.

Kramer (1983) says that an individual becomes a dialectical thinker when she/he starts to accept of contradictions, conflicts, constant change of knowledge, and be able to integrate those holistically. Owe to dialectical thinking, by integrating paradoxical and contradictory knowledge, ill-defined problems and dilemmas can be resolved.

2.1.2.3. Links between Design and Postformal Thinking

According to Commons and Ross (2008), post-formal thought refers to behaviours found in the most complex stage and places a greater emphasis on both problem solving and problem finding. Reminding Schön's words would be befitted here; according to Schön (1983), "problem of design problem" is finding the problem. Indeed, finding the design problem mostly not enough for solving it, the designer needs to reframe the problem in order to identify it. Post-formal thought ability allows the individual to restructure problems according to possibilities. So, to identify design problems and reframe them, individual should be at post-formal thought stage.

According to Lawson (1980), design problems are multi-dimensional and highly interactive. Because of the complexity of design problems that involve lots of variables, with Schön's words, every design moves cause multiple outcomes and a designer should know how to deal with them in addition to keeping under control of multiple relations. Designers know that there are other possible solutions to the problem and try to find a befitted solution among the others. In other words, she/he doesn't reject other solutions but applies the one which working best for the whole design. It can be assumed from this viewpoint that designers should be at higher sub-stages than Systematic Stage. Because of the fact that design deals with complex systems, designers call for chaotic thinking which is an iteration between analysis, synthesis and evolution within the system or/and among systems. For example, during a design process, the designer should consider the biological system, physical systems, abstract system, engineering system, cultural and ethical system, ecological system, economic system, and so on. Also, the designer needs to compare and contrast systems in order to border her or his framework. In addition to this, both reframing problems and overcoming of systems contradictions needs transforming and modifying system or systems. So, in the design process, the designer may apply all these characteristics of the metasystematic stage in order to establish a proper solution.

As mentioned before at post-formal thought stage, there are two prominent types of thinking; relativistic and dialectical. In relativistic thinking, individuals aware of that the problems can be viewed from many perspectives, so, individuals choose one which is the most relevance to the problem. This kind of utility and pragmatism reminds us of Schön's rigour vs. relevance argument. According to Schön (1983), the dilemma of rigour or relevance arises from the insistence on to solve real-life problems in closed-systems by applying technical knowledge which constituted by research-based theory and techniques to wicked problems. But, as we all know, real-life problems cannot be easily solved by only setting 'rational' or 'scientific' approaches to work. Indeed, this kind of insistence is just an outcome of formal thought. Contrary to rigorousness and shallowness of formal thought and scientific thinking, post-formal thought values relevance; works in open-systems and let individuals to think more complex and creatively. Thus, according to Wu and Chiou (2008), relativistic thinking is a source of greater diversity and novelty.

At the second type, dialectical thinking, similar to Schön's identification of dialectic between design and designer, individuals aware of their thoughts and apprehend that thoughts to be in a process of evolution. Thus, dialectical thinkers know that they can break open commons and/or traditions and act more creatively. We can keep track of dialectical thinking in Petra's and Quist's conversation too; when Petra, an architecture student stuck at the design process, consults her teacher, Quist, and ask for help about the screwy site, Quist advices that "you should begin with a discipline,… you can always break it open later" (Schön, 1983, p.85). As it is said before, means of Schön's reflection is a kind of dialectic between design and designer. Just like as Quist's advice, designers know that they can always break their on-going validations if their reflective conversation with situation and oscillation between the whole and the unit reflects that on-going validations lead her/him to an unsatisfactory solution or a dead end.

To summarize, post-formal thinking let individuals gain abilities to consider the problem from multiple perspectives; determining relations among variables and possible multivariate causes, keeping under control of multiple relations and outcomes; comparing, contrasting, transforming, and synthesizing prescribed systems; reframing problems and overcoming systems contradictions; and finally emphasizes of creativity. These sound so familiar with design since design also has those features too. Also, contrary to traditional science education, design education aims to introduce and teach those features to design students. And also, it is good to remind that, post-formal thinking is a must level for creativeness and innovativeness.

2.2. Creativity and Design Process

While the design process is a creation, everyday cognition of the ordinary minds is responsible for creativity. Thus, it is important to pinpoint the distinction between which is created, and which is creative (Ward et al., 1999). To make this distinction, researchers have focused on different aspects of creativity and mind throughout history, and tried to define what creative design is. Yet, there still is not a consensus on what creativity is. The main problem to reach a consensus on creativity definition is closely connected to shifts in creativity concepts. From ancient times to modern era, creativity concepts have been shifted from craft to a spiritual characteristic; to activity of self-discovery; to a sudden realization, inspiration and insight moment; and to a discovery by connecting pre-existent information and/or knowledge (Albert and Runco, 1999; Sawyer 2006).

In 2010, Panagiotis G. Kampylis and Juri Valtanen collected 42 prominent creativity definitions and determined the outstanding keywords used, which are novel and appropriate. Novelty refers to achieve a new output, which its origins are not obvious and cannot be recognised, by using a new way to assessing to the already existed knowledge in the cognitive system (Peterson, 2002), and appropriateness refers to being valuable and useful in a specific domain (Wong, 2013). The characteristic acts of the creative process are combining, synthesizing, bridging, generating, transferring and connecting (Kampylis and Valtanen, 2010). In design science-based creativity and creative process, definitions root to prior creativity research and share the same keywords and characteristics. Thus, it is better to skim creativity research in general before examining creativity in the design process.

2.2.1. Creativity Research

Due to viewing creativity as a personal characteristic was a dominant approach, the very early scientific research of creativity and cognition were based on exposing the relationships between intelligence (IQ) and creative performance. As an example, Catharine M. Cox (1926), concluded that there is a correlation of .16 between IQ scores and eminence of participants, and claimed that exceptionally intelligent people are also creative. However, starting from the 1950s, researchers tried to demonstrate creativity is a different human characteristic then IQ. Latter research proved that creativity and intelligence are not completely reliant on each other, but there is a threshold to reach a creative achievement (Runco, 2007). Joy Paul Guilford (1967) was one of the researchers came up with the conclusion that although high IQ is not a must for divergent production ability, it is a necessity. Simply, according to threshold hypothesis, above-average intelligence is needed for high creativity, but it is not solely sufficient (Guilford, 1967). The threshold is usually set to an IQ of 120 (Jauk et al., 2013). According to the threshold hypothesis, individuals who have IQ scores below 120 should have limited creativity, yet above 120 IQ is no longer effective on creative performance. In many research, it is proved that intelligence is not a direct indicator of creative performance at all (Kim, 2005; Preckel et al., 2006; Runco and Albert, 1986; Wallach and Kogan, 1965). In 1976, Dean Keith Simonton checked thoroughly Cox’s data and found no correlation between IQ scores and eminence of participants. Michael A. Wallach and Nathan Kogan (1965) concluded game-like creativity (non-speeded) tests results and intelligence are uncorrelated. Kyung Hee Kim (2005), rejected the threshold theory due to findings showed a negligible correlation, r = .174. Although there still is none consensus on whether there is a threshold, or intelligence and creativity are related to each other, the research on these provided a solid ground for contemporary creativity conceptualization.

With his pioneering and seminal studies, Guilford's (1950, 1967) creativity research was rooted from intelligence and creativity relations and remained as the beginning of current creativity theorizing. Guilford's conceptualization was based on describing intelligence as a multi-dimensional and non-hierarchical entity (Guilford, 1950). Guilford (1967) classified 17 distinct characteristics (and 180 combinations of these characteristics) of intelligent (please see Table 1), and grouped those under three categories in order to define and organize human cognition:

- Operations (contains 6 characteristics)
- Contents (input) (contains 5 characteristic)
- Products (output) (contains 6 characteristic)

Table 1. Guilford's classification.

Operations	Contents	Products
Cognition	Visual	Units
Memory recording	Auditory	Classes
Memory retention	Symbolic	Relations
Divergent production	Semantic	Systems
Convergent production	Behavioural	Transformations
Evaluation		Implications

With the help of his Structure-of-Intellect model, Guilford (1950, 1967) argued that these characteristics and combinations of them are not independent each other, yet they are related, and come about by means of divergent production, defined as the ability of generating multiple solutions to a problem: creativity, whereas convergent production is the process of deducing a single solution to a problem. These two systems; divergent and convergent thinking, widely accepted by design researchers as the base of creative reasoning. According to Goldschmidt (2014) "there is evidence that creative thinking involves both divergent and convergent thought" (p.46) and "the balance between them is particularly pertinent to the understanding of creative thought" in design (p. 45) Similarly, van der Lugh (2003) states that creative problem solving involves both divergent and convergent phases: during the divergent phase people generates ideas by brainstorming and during convergent phase the generated ideas are evaluated. Where divergent thinking provides novelty, convergent thinking verifies appropriateness. Arthur Cropley (2006, p.391) defines convergent thinking as:

> Convergent thinking is oriented toward deriving the single best (or correct) answer to a clearly defined question. It emphasizes speed, accuracy, logic, and the like and focuses on recognizing the familiar, reapplying set techniques, and accumulating information. Therefore, it is most effective in situations where a ready-made answer exists and needs simply to be recalled from stored information or worked out from what is already known by applying conventional and logical search, recognition, and decision-making strategies. One of the most important aspects of convergent thinking is that it leads to a single best answer and, thus, leaves no room for ambiguity: Answers are either right or wrong.

Convergent thinking has many characteristic similarities with formal thinking. The most obvious similarity between them is both yields to a single answer. Thus, for both thinking styles, there is no room for ambiguity, nor contradictions. Although the existing knowledge can be manipulated, both thinking styles are dependent on the existing knowledge, thus work in closed-systems. To do so, the problem must be well-defined.

According to Keith Sawyer (2006), one of the main differences between convergent and divergent thinking is whereas intelligence depends upon convergent thinking, creativity depends upon divergent thinking.

> Divergent thinking, by contrast [to convergent thinking], involves producing multiple or alternative answers from available information. It requires making unexpected combinations, recognizing links among remote associates, transforming information into unexpected forms, and the like. Answers to the same question arrived at via divergent thinking may vary substantially from person to person, but be of equal value. (p. 391)

As the convergent thinking has similarities with the formal thinking, the divergent thinking has similarities with post-formal thinking. Both divergent thinking and post-formal thinking works in open-systems, thus both of them allow to connect unrelated knowledge and information in order to produce multiple answers for ill-defined problems.

Besides the research on two thinking modes of creativity, some researchers, such as James Melvin Rhodes, have focused on determining components and dominant factors which have an impact on creativity. In 1961, Rhodes reported that he collected and analysed more than forty definitions and observed that they were overlapping and intertwining. According to him to understand creativity, one should approach it as a holistic formation constituted by four strands (Rhodes, 1961, p.307). Rhodes (1961) calls these strands as the four P's of creativity: person, process, press and products. He further explains what these terms stand for as:

- Person: "personality, intellect, temperament, physique, traits, habits, attitudes, self-concept, value systems, defence mechanisms, and behaviour" (p. 307).
- Process: "motivation, perception, learning, thinking, and communication" (p. 308).
- Press: "the relationship between human beings and their environment" (p. 308).
- Product: "a thought which has been communicated to other people in the form of words, paint, clay, metal, stone, fabric, or other material" (p. 309).

By bringing clarity to concepts of creativity, Rhodes's four P's accepted as creativity research focus groups in the field. Since this thesis focuses on the relationship between post-formal thinking and creative design process, only the Creative Process concept is further examined.

2.2.2. The Creative Process

One of the oldest creative process models proposed by John Dewey in 1910. He defined five intertangled stages in the context of cognition: at the first stage individual feels a difficulty; at the second stage the problem causes the difficulty is defined; at the third stage individual proposes potential solution to the problem; at fourth stage the proposed solutions are advanced, and at the final stage individual test the final solution proposals, and accept or rejects them (Figure 1). Although the model fits better with the problem-solving process, and Dewey does not give more information on how the creativity outputs, his model was accepted one of the pioneers.

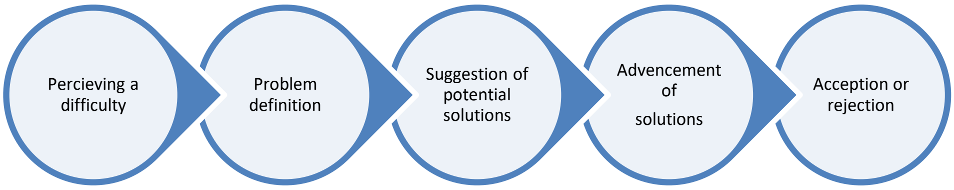

Figure 1. The five stages of creative process of Dewey

After Dewey, in 1928 Graham Wallas published his four stages creative process model (Figure 2). These four stages are preparation, incubation, insight, and verification (Sawyer, 2006).

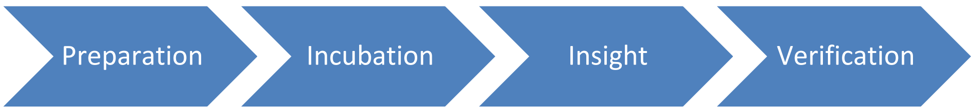

Figure 2. The four stages of creative process of Wallas

Preparation is the stage where the individual searches for the related knowledge and collecting data and information (Wallas, 1970). In this phase, individuals encode the new data and knowledge by relating them with existing schemata, then modify the schemata to align the new data with, and finally restructure the schemata through pattern generation (Armbruster, 1989). To simply put, at this stage, individuals internalize the domain knowledge. At incubation stage individual unconsciously works on the newly acquired knowledge and create a new schema (Armbruster, 1989). Due to being an unconscious occurrence, little is known about this stage, and as it cannot be examined latter researchers avoided including this step into their models (Wong, 2013). Yet, during incubation, some newly gained mental structures surface into consciousness (Sawyer, 2006). These insights are called "Eureka!", "Aha!" experience or as "creative leap", "Creative insights" (Armbruster, 1989, Cross, 2006). As soon as the insight surface into consciousness, it is subjected to verification. At verification stage, individual evaluates the insight against to internal and external standards (Armbruster, 1989). If the idea is good enough to satisfy standards then the individual elaborates it in order to reach a final output (Sawyer, 2006).

Mostly based on Dewey's, Wallas's and Guilford's pioneering models, many process models are presented in years. In 2008, Thomas Howard and his friends analysed 19 models (Table 2) and they concluded the phases of the models can be grouped as analysis, generation and evaluation (Figure 3).

Table 2. Creative Process Models (Source: Howard et al., 2008, p.12)

Models	Analysis Phase	Generation Phase	Evaluation Phase
(Helmholtz 1826)	Saturation	Incubation / Illumination	
(Dewey 1910)	A felt difficulty / Definition and location of difficulty	Develop some possible solutions	Implications of solutions through reasoning
(Wallas 1926)	Preparation X	Incubation / Illumination	Verification
(Kris 1952)	X	Inspiration	Elaboration
(Polya 1957)	Understanding the Problem / Devising a Plan	Carrying out the Plan	Looking Back
(Guilford 1957)	X	Divergence	Convergence
(Buhl 1960)	Recognition / Definition / Preparation / Analysis	Synthesis	Evaluation
(Osborn 1963)	Fact-finding	Idea-finding	Solution-finding
(Parnes 1967)	Problem, challenge, Opportunity / Fact-finding / Problem finding	Idea-finding	Solution-finding
(Jones 1970)	Divergent	Transformation	Convergent
	Search for Data / Understand the Problem	Pattern finding / Flashes of Insight	Judgement
(Stein 1974)	X	Hypothesis formulation	Hypothesis testing
(Parnes 1981)	Mess Finding / Fact-finding / Problem finding	Idea-finding	Solution-finding
(Barron *et al.* 1981)	X	Conception / Gestation / Parturition	X
(Amabile 1983)	Problem or task presentation / Preparation	Response generation	Response validation
(Couger *et al.* 1993)	Opportunity, Delineation, Problem Definition / Compiling Information	Generating Ideas	Evaluating, Prioritising Ideas
(Isaksen *et al.* 1994)	Constructing Opportunities / Exploring Data / Framing Problem	Generating Ideas	Developing Solutions
(Shneiderman 2000)	Collect	Create	
(Basadur *et al.* 2000)	Problem Finding / Fact Finding / Problem Definition	Idea Finding	Evaluate and Select
	Diverge – Converge at each stage		
(Kryssanov *et al.* 2001)	Functional Requirements / Structural Requirements	Functional Solutions / Analogies, Metaphors	Reinterpretation

Figure 3. The three stages of creative process of Howard et al. (2008)

According to Howard et al. (2008), at analyses phase the given or found problem is analysed, re-structured and the related knowledge are gathered in order to solve the problem. In generation phase ideation occurs, and in the evaluation phase, the possible solutions are tested. After grouping the phases in models, they compared grouped phases with the engineering design process stages and design outputs and concluded that for an *original design output* creative performance peaks at generation phase, which occurs at *Conceptual Design* stage of the design process (Figure 4).

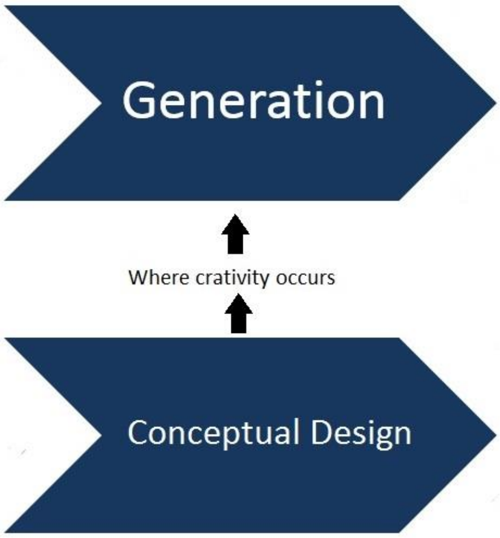

Figure 4. The stages creative performance peaks at creative and design processes for an original design output (Source: Howard et al., 2008)

Although, Howard et al. (2008) did not give more information on generation phase itself, or why the creative performance peaks at this stage, there are some studies in the literature which seeks answers on the creativity phenomenon (Finke et al., 1992; Mednick, 1962; Sawyer, 2006; Ward et al. 1999). These studies are grouped as romantics and non-romantics (Boden, 1990). The romantic studies accept the creativity as a mysterious, subconscious occurrence, and do not seek further on how it occurs. On the contrary, the non-romantics also called combination-theorists focus on how creativity occurs. According to these non-romantic studies, “creators work on many problems at the same time, and that in most creative careers, an insight often generates, even more, questions than it answers” (Sawyer, 2006, p.70). With the occurrence of new questions, individual needs to reformulate the problem, which ends up with mini-insights that generate new questions. Thus, creativity does not occur in a single moment, but bit by bit, with a hard mental workload, and thus can be traced:

> Every so often a creator will have a subjective experience of a moment of insight. But even though it may seem sudden to the creator at that moment, in retrospect it can always be traced to the prior work that the creator was engaged in. By analysing the sketches and notebooks leading up to the insight, we see that each innovation resulted from a connected, directed, rational process (Weisberg, 1986, 1993). […] We only think we see leaps of insight because we didn’t observe the many small, incremental steps that preceded the “insight.” Creative activities require problem-solving and decision making throughout the process, and each one of these decision points involves a small amount of creative inspiration; yet, when these mini-insights are viewed in the context of the ongoing creative work, they no longer seem so mysterious. (Sawyer, 2006, pp. 71-72)

As one of the pioneering combination-theorists Arthur Koestler (1964) describes the creative process is forming new relations between previously unrelated knowledge chunks and matrices of thoughts. According to Koestler (1964), the creative process is the finding of covered similarities and *bisociate* them in order to generate a creative idea (Figure 5):

> The pattern underlying […] is *the perceiving of a situation or idea, L, in two self-consistent but habitually incompatible frames of reference, M_1 and M_2.* The event L, in which the two intersect, is made to vibrate simultaneously on two different wavelengths, as it were. While this unusual situation lasts, L is not merely linked to one associative context, but *bisociated* with two. (p. 34)

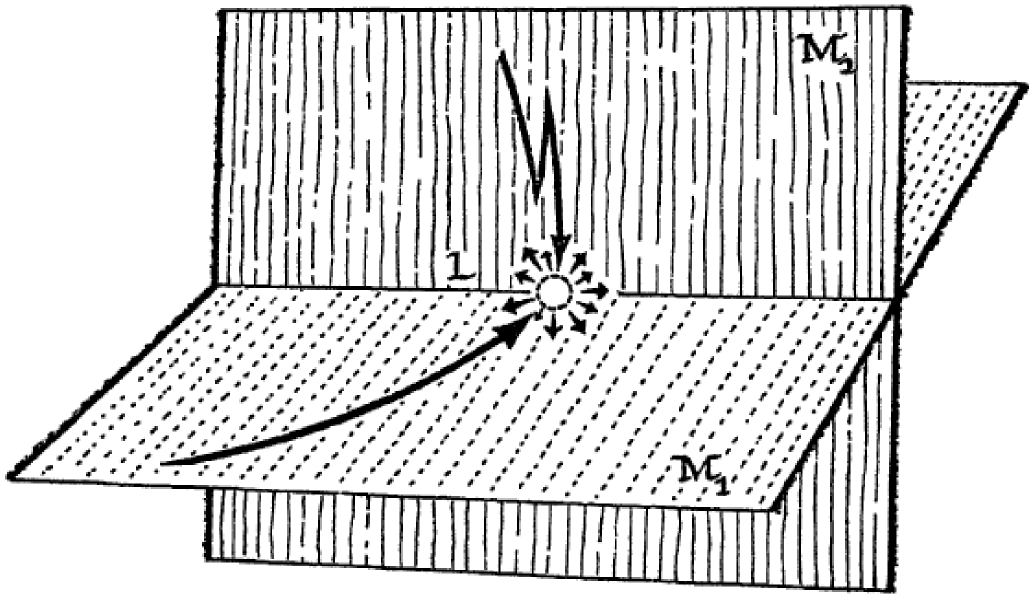

Figure 5. Koestler’s bisociation (1964, p.36)

This *double-mindedness* causes a temporary disequilibrium on schemata and forms a creative idea (Koestler, 1964). The instability arises from connecting two or more unrelated matrices generates more questions that need to be answered to reach equilibrium. By doing this, individual creates new connections of an uncommon knowledge which gives birth to a creative output. Cross (1997b) calls this birth as a *creative leap.* According to Koestler (1964), this creative leap is the “fusion [of] a new intellectual synthesis” (p.45), and it does not occur out of blue.

In the Associative Theory, Sarnoff Mednick (1962, p. 221) describes the creative process as “forming of associative elements into new combinations which either meet specified requirements or are in some way useful.” According to him, novel and valuable insights are the combined concepts from different conceptual spaces which creates new knowledge. Similarly to Mednick, Roger Schank and Chip Cleary (1995) and Arne Dietrich (2004) point out the importance of synthesis of different knowledge/concepts in creativity process:

> Creativity is the epitome of cognitive flexibility. The ability to break conventional or obvious patterns of thinking, adopt new and/or higher order rules, and think conceptually and abstractly is at the heart of any theory of creativity (Dietrich, 2004, p.1014)

Margaret Boden (1998) explains the generation of novel ideas as the exploration and transformation of old conceptual spaces by mapping. A conceptual space is a knowledge network linked according to their associations (Warr, 2007). According to Boden (1995), "different conceptual spaces have distinct structures, each with its own dimensions, pathways, and boundaries", and exploration and transformation are two different ways. In exploration, the individual seeks "an unknown niche in a pre-existing conceptual space" (p.4), and it is less creative than transformation. In transformation, an individual transforms one or more dimensions of the space by adding or removing constraints. Boden (1998) points out that "The more fundamental the transformation, and/or the more fundamental the dimension that is transformed, the more different the newly-possible structures will be." (p. 348)

Subrata Dasgupta (1996) claims creativity is gradualistic because ideation is "nothing more than a knowledge level process" (p.183) and "large insights are composed of a possibly intricate but describable network of small steps" (p.208). Thus, although sudden insights might seem like a miracle of a genius, they are just the precious products of a complicated cognitive process where knowledge is transformed into a new and uncommon one.

As seen in the given theories above, creativity is the output of highly structured processes, and it is very systematic and organized. Based on these theories, Figure 6 summarizes the generation of a creative idea:

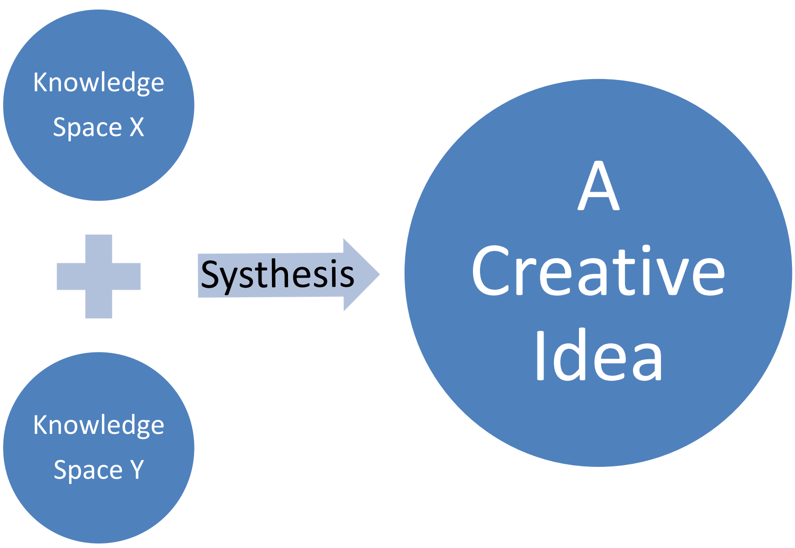

Figure 6. Generation phase of creative process

As on the theories are given above, to reach a creative output, an individual should synthesis a new idea from two or more knowledge spaces. This synthesis generates the experience of 'Eureka!' or "A-ha!" moment. Thus, as Goldschmidt and Tatsa (2005) state that "every creative outcome can be traced back to good ideas that started it off' (p.593).

2.2.3. The Creative Design Process

According to Chris Jones (1970), the design is a creative activity with a goal that creating something new and useful. Hence, the design has three stages: divergence search, transformation and convergence. Divergence search stage is the phase of searching everything connected with the problem, especially inconsistencies and conflicts. According to Jones (1970), at this stage, in order to avoid preconceived solutions, designers increase their uncertainty by gathering a mass of information which can be related to the problem and solution space. By doing this, designers be able to de-structure the design problem. After a sufficient divergence has occurred, and the design problem decomposed, transformation stage starts. This stage is the one with high-level creativity. Pattern-making is the main activity of this stage. The gathered data at the divergence search stage are mapped at this stage. "Pattern-making, in this context, is the creative act" (p.66). As in the creative process, at transformation stage, connecting the unrelated information/knowledge in a successful way is the main goal. At convergence stage, designer eliminates the secondary uncertainties until she/he reaches a final solution which is concrete and detailed. If reaching a final solution fails, designers shift back to transformation stage and re-map the gathered data at the divergence search stage.

Horst Rittel (1973) suggests design process has six discrete steps. The process begins with understanding, defining, and formulating the design task. The second step covers collecting data. At the third step, designers analyse the obtained data and compare it with the design task. The fourth step is the one when the solutions are developed. According to Rittel (1973), creativity occurs at this step as designers synthesize new knowledge from the analysed data to reach potential desired solutions. The fifth stage is the elimination of the suggested solutions. Sixth and final step covers the testing and implementation of the chosen solution.

Mary Beth Rosson and her colleagues (1987) determined that the design process has three main iterative phases by interviewing 22 designers. These are a logical analysis of the design problem, discussion, and iterative development activities. According to their analysis of the interviews, designers analyze and re-structure the problem first, then they gather related data from multiple knowledge domains, and finally synthesize an appropriate solution for the re-structured design problem.

Micheal J. French (1985) developed a four stages design process model: analysis of the problem; conceptual design; the embodiment of schemes; detailing. The first stage covers analysing and defining the problem, determining limitations and needs. The second phase, conceptual design, is the most important stage in the context of decision making. At this stage, designers generate several ideas to solve the design problem. It also is the stage insights and *Aha!* moments occur. An embodiment of schemes stage covers working up in greater detail on the schemes and choosing a final decision. At the last stage, designers deal with the small details to improve the quality of the end product.

In 1997, Cross suggested a four problem-oriented non-linear activities design process model: exploration; generation; evaluation; and communication. Exploration is the activity where designers formulate a poorly defined design problem, define a problem space and solution space side by side. Generation activity is the one designers generate design proposals. These proposals are generated by minor or major modifications. Where minor modifications do not result in creative outputs, major modifications result with completely new outputs which are creative. And the final activity, communication is the medium for conveying the results of the other three activities.

According to many researchers, similar to the creative process, the design process can be group under three main phases: analysis, synthesis and evaluation (e.g. Alexander, 1971; Asimow, 1962; Jones, 1970; Watts, 1966). Because of the iterative nature of design, these three phases are not linear, but iterative, and thus back and forward loops happen many times in a design session till reaching the desired solution (Figure 7).

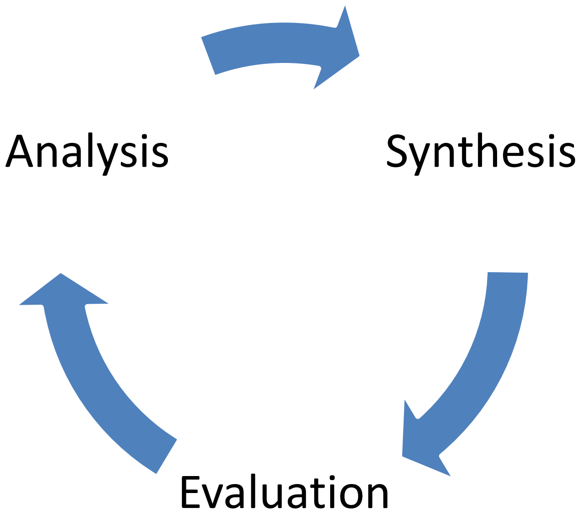

Figure 7. Phases of design process

By analyzing 23 different design process models, Howard et al (2008, p. 164) concluded that although "design process models are poor with regards to representing creative processes", for an original design output designers should focus on conceptual design stages of design processes. Leonard Bruce Archer (1984) also claimed that the creative act is always in the middle of the design process. When the models given in this section are evaluated, it can be seen that the idea/solution generation phases are also praised for the occurrence of creativity.

When the creative process given in Section 2.2.2 in detail is compared and combined with the design process, it can be said that both processes go through almost same phases (Table 3):

Table 3. Creative Design Process Model

	Analysis		**Idea Generation**	**Evaluation**
Activity	Defining and restructuring problem	Data and knowledge gathering	Idea generation by synthesizing of the data and knowledge	Assessing the novelty and appropriateness of proposed solution

The first highlighted vital activity for creativity by both creativity and design researchers is the importance of gathering data and knowledge from different and/or distant domains. Koestler (1964), claimed that the creativity occurs when the previous matrices seen to be incompatible are linked. According to him, at the *incubation* stage, the mind keep scanning a different matrix unconsciously to link it to the related matrix in order to solve the problem. Cross (2006) said *creative leaps* are kind of bridges connected two unconnected spaces as *apposite* proposals. Thus, the exploration of the problem and solution spaces are vital. Boden (1995) highlighted that the exploration of the conceptual spaces is important due to transformation depends on how much the exploration deepens. Ward (1998) claimed transformation of knowledge from distant domains to target domain enhances the creativity. According to Santanen et al (2002) combining mutually remote bundles of knowledge results more creative outputs. On the contrary, using close domain knowledge decreases creativity. The reason of this is the "*Einstellung* effect [which] occurs when the first idea that comes to mind, triggered by familiar features of a problem, prevents a better solution being found." (Bilalic et al, 2008, p. 553). David Tall (2008) calls these first ideas that come to mind as *met-before*. Further, he gives '2+2 makes 4' as a simple example for a met-before. As in the example, a met before is an instant answer to a problem which might block looking for further alternative solutions. So, for achieving a creative output, it is crucial to connect different knowledge chunks and avoid being stuck in *met-befores*.

The second highlighted vital activity for creativity is idea generation by synthesizing prior knowledge. According to Boden (1995, p.126) "exploring a conceptual space is one thing. Transforming it is another." The knowledge transformed a new one can belong to a different domain or target domain. But it is also important how it is mapped, and its constituents. For ill-structured problems, the problem-related knowledge is mostly unrelated and interconnected. This ambiguity makes defining them almost impossible. According to Atman et al. (1999), focusing on defining a problem cause to fail to move on generating ideas yield solutions, yet focusing solely on the idea generation yield to come up with a simple problem definition which causes a fail on the quality of the solution. Thus, solver should reframe the problem as sub-problems and generate ideas yield sub-solutions. By this way "[p]roblem and solution are developed in tandem, by exploring the problem space and the resulting solution spaces together" (Jennings, 2010, p.24). This model is called as Co-evolutionary Design Model (Maher, 2001), and is one of the two design process models based on combinational theories.

According to this model, a transformation occurs between problem and solution spaces. According to Cross and Dorst (1998) designers work in the problem space until they notice a pattern which can generate ideas. Once the pattern is recognised, designers explore the possible correspondents of this pattern and transform it iteratively. The transformation of ideas can be grouped into two types: conceptual expansion and conceptual shift (Figure 8).

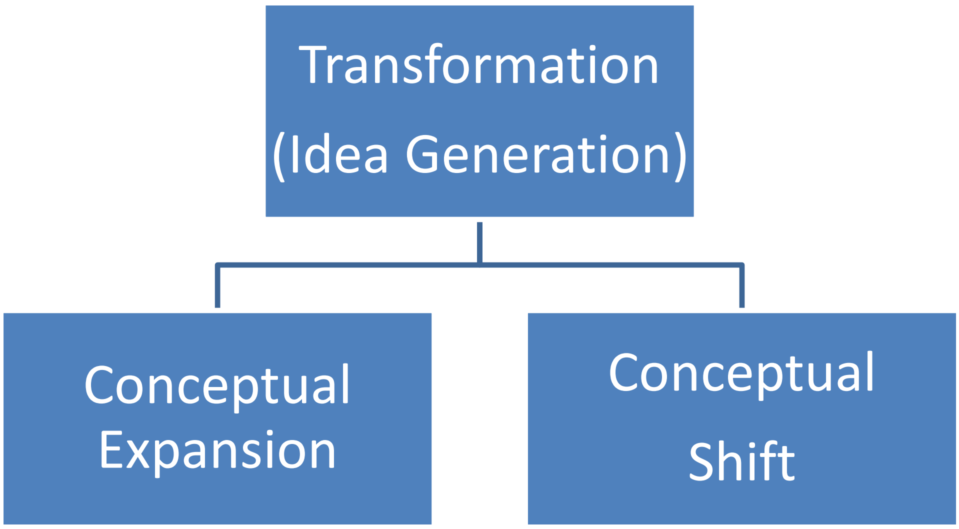

Figure 8. Types of transformation (idea generation)

The conceptual expansion extends boundaries of existing concepts by adding seemingly irrelevant knowledge to it (Hampton, 1987; Wan and Chiu, 2002; Ward et al., 2002; Ward et al., 1997). According to Vinod Goel (1995), conceptual expansion is a *vertical* transformation where the existing idea is more detailed, which is expending the conceptual space. “An architects adaptation of an existing building to a new use” (Nevid, 2012, p.261), or using a paper-clip as a hair-grip are examples of conceptual expansion. As can be inferred from the examples, for a conceptual expansion relativity becomes prominent. Because of the conceptual space already exists, and it just *vertically* transforms the solution space, this type of transformation is not much creative as conceptual shift (Ward, 1997; Goel, 1995).

Conceptual shift “involves the transformation of some (one or more) dimension of the space, so that new structures can be generated which could not have arisen before. […] The more powerful the transformation, the more surprising the new ideas will be." (Boden, 1998, p. 349). Goel (1995) calls this type of transformation as *lateral*. The conceptual shift occurs when the two different and unrelated ideas are synthesized into one in order to create a new idea. For example, the conceptual shift of *sandwich* to the *flame sandwich* (which means a bad comment between two good comments) (Benczes, 2011), implementing rail idea to the curtain rod or coming up with Theory of Relativity just by observing the trains. As can be inferred from the examples, for a conceptual shift irrelation becomes prominent.

The second design process model based on combinational theories is Function–Behaviour–Structure (FBS) Model (Table 4) developed by John Gero. FBS model is the "best-known and best-developed attempt to offer a generic categorization scheme that is claimed to be valid across design domains and design tasks" (Goldschmith, 2014, p. 31). According to Gero (1990, p.28):

> The purpose of designing is to transform function F (where F is a set) into a design description D in such a way that the artefact being described is capable of producing these functions. For example, when designing windows, some of the functions include the provision of daylight, control of ventilation, and access to a view. The design description would take the form of drawings and notes. Thus, a naive model of design is F → D, where → is some transformation. There is, however, no direct transformation capable of achieving this result.

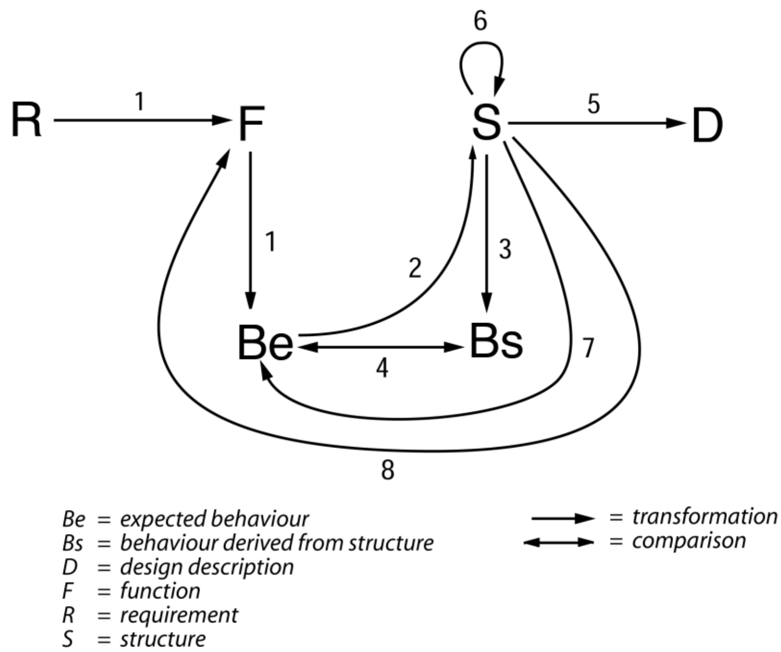

Figure 9. The FBS ontology of designing
(Source: Gero and Kannengiesser, 2014, p.267)

As the function (F) cannot be directly transformed to design description (D) indirect transformation occurs. There are two basic transformations; first one is the transformation of structures to design descriptions (S → D), and the other one is the transformation of functions to structures (F → S). Yet, according to Gero (1990), these kind of transformations are the direct mapping forms, and thus cannot be considered as designing. To be considered as designing, transformations should also include behaviours. There are two types of behaviours; first of them is behaviours of the structures (Bs) and can be directly derivable from structures (S → Bs). The second is the expected behaviours (Be) and can be derived transformation of functions (F → Be). Besides these, in the design process, there might be also two other types of expected outcomes; expected structure (Se) and expected function (Fe) (see Figure 9).

Table 4. Examples of function, behaviour and structure of different artefacts (Source: Gero and Kannengiesser, 2014, p.266)

	Dwelling	**Editing software**	**Manufacturing process**	**Team**
Function (F)	Provide safety, provide comfort, provide affordability	Be time efficient, provide affordability	Be safe, be time efficient, provide sustainability, provide affordability	Be time efficient, provide affordability
Behaviour (B)	Strength, weight, heat absorption, cost	Response times, cost	Throughput, accuracy, speed, waste rate, cost	Working speed, success rate, cost
Structure (S)	Geometrically interconnected walls, floors, roof, windows, doors, pipes, electrical	Computationally interconnected program components	Logically and physically interconnected operations and flows of material and information	Socially interconnected individuals

There are eight fundamental transformations or sub-processes in FBS model (Gero and Kannengiesser, 2014). The first one is Formulation, and occurs when a requirement is transformed to function (R → F) or function is transformed into expected behaviour (Be → S). The second sub-process, synthesis, occurs when expected behaviour is transformed into the structure (Be → S). Analysis occurs when the structure is transformed into the behaviour structure (S → Bs). When expected behaviour compared with the behaviour of structure evaluation sub-process occurs (Be → Bs).

“Documentation produces an external representation of a design solution for purposes of communicating that solution” (Gero and Kannengiesser, 2014, p.273) and occurs when the structure is transformed to design description (S → D). The last three sub-processes are reformulations of the state of structures. Type 1 is the transformation of the structure to a new structure (S → S’), type 2 is the transformation of the structure to expected behaviour (S → Be’), and the last one is the transformation of the structure to expected behaviour first and then to function (S → F’ (via Be)).

To sum up, for a creative design process, designers should focus on to collect data from different knowledge domains and synthesise them in order to reach a conceptual shift. So, basically, finding a satisfactory solution does not always mean it will be creative. If the base ideas are not bright enough, the solutions are generated from these ideas would be destined to fail in the context of creativity. Similarly, the success of the transformation of the base ideas is also crucial as direct mappings, such as F → S prohibits reaching to a creative synthesis. Thus, the idea generation quality has indisputable impacts on creative design thinking (Goldschmith and Tatsa, 2005; van der Lugt, 2003).

2.2.4. Assessing the Quality of Creative Design Process

In the literature, there are two types of measuring approaches to assess idea generation quality in the creative design process which is rooted in combinational theories. The first approach is based on the quantity of generated ideas (i.e., productivity) in a given design session. As explained in previous chapters, creativity occurs when two unrelated matrices have merged with each other to create a new idea. Thus, the basic rationale of productivity approach is if the number of generated ideas is large, the solution space would contain more high-quality ideas (Osborn, 1953). Alex F. Osborn, the father of brainstorming, claimed that creativity can be boosted by boosting productivity, and quantity leads to quality. Similarly, Diehl and Stroebe (1987) concluded that generating fewer ideas yields fewer good ideas. Similarly to Diehl and Stroebe (1987), Gallupe et al. (1991) and Valacich et al. (1993) are also equivocating producing a large number of ideas with idea generation quality. In 1958, Donald W. Taylor and his colleagues experimented on forty-eight participants’ problem-solving activity to measure creative performance. Simply, they counted a number of ideas produced by teams (twelve in total) by discarding duplicated ideas and compared to each other. Yet, Andrew Martin Warr (2007) argued that the validity and reliability of the research by pointing out that the researchers accepted all the ideas as creative, as well as the protocols parcelled only by one judge. Similarly, Goldschmidt (2014) criticized this assessing approach by pointing out that quantity of generated ideas might be high because of repetitions or the vast majority of the ideas might be weak. As Warr (2007) and Goldschmidt (2014) remarked, not all the ideas and /or proposed solutions can be creative. For example, assigning red as the colour of a product, or deciding to use firebrick as a material can be regarded as design ideas. Yet, as seen from the examples, these decisions cannot be accepted as creative without looking the effect of these decisions on the overall process. Thus, assessing the idea generation process quality by just measuring the quantity of generated ideas is controversial.

The second approach to assessing idea generation process quality is measuring the quantity of generated links between the ideas. This assessment method is an upgraded version of counting the ideas. In this method, instead of counting the ideas, process quality is assessed by analyzing the connectivity of ideas and the overall impact of the ideas on the process. As mentioned before, designing is an activity that transforming knowledge to generate ideas, connecting these ideas to reach sub-solutions, and then merging the sub-solutions in order to reach a final design. Thus, connectivity and integrity have crucial roles in the quality of idea generation process. Dorst (1997) explains this by saying:

> [A] product is a network of thought-out forms and properties, of objects and thought-out links between them which have been instilled with meaning. I would like to point out that in such a definition a 'product' is the total network of decisions (…) Design thus becomes a thought process aimed at building a network of decisions (…) (p.35)

Based on the theory that design as a networking activity, researchers focus on the integrity to evaluate creative design process by quantifying the density, connectedness and criticality of generated ideas. According to van der Lugt (2003), idea generation productivity can be assessed by looking at the number of generated connections, and creative ideas tend to generate rich networks. As van der Lugt, Goldschmidt and Tatsa (2005) indicate that finding creative solutions is closely connected to a number of generated links between design moves, as also known as a design decision and design ideas. Thus, according to researchers (e.g. Dorst, 1997;

Goldschmidt, 2014; Goldschmidt and Tatsa, 2005; van der Lugt, 2003), to assess idea generation process quality, one should look at the ratio between generated ideas and the number of links between the ideas. The ratio between generated ideas and the number of links between them called as *Link index* and it is a quantitative dependent variable used to assess idea generation productivity and density of synthesizing effort (Please see Section 3.2.1.5. for further information). According to this approach, while link index is used for assessing productivity quality, creativity can be assessed by analysing the design ideas which create outnumbering connections. According to researchers, a creative idea creates a novel and appropriate conceptual frame which stimulate the productivity by breeding many new ideas (e.g. Akın and Lin, 1995) Cross, 1997; Dorst, 1997; Goldschmidt, 2014; Goldschmidt and Tatsa, 2005; Bilda and Gero, 2008; van der Lugt, 2003). Goldschmidt (2014) calls this kind of design ideas as *Critical moves* which "are keyframes in the thinking process that are associated with the novelty of design." (Warr, 2007, p.15) (Please see Section 3.2.1.4. for further information). Cross (1997a) showed that critical moves are the *breakthroughs* on concept-formation, thus can be regarded as *creative leaps*. Critical moves are quantitative dependent variables which have a high impact on the design process and the final product. Thus, critical moves can be used as a reliable indicator of creativity while assessing the quality of idea generation process.

CHAPTER 3

THE EMPIRICAL STUDY

Two tasked experimental study was conducted to answer the questions whether there are relations between creativity in design and cognitive development levels of designers. The first task, Social Paradigm Belief Inventory, provided to assess participants' creativity in design and cognitive development levels of designers. The second task, performing think aloud method of solving a design problem provided to assess participants' linkographic entropies. To have a better understanding in which way and domains creativity in design and cognitive development effect each other, SPBI scores and linkographic entropies were correlated. Then, a syntactic analysis is performed in order to assess the roles of postformal thinking types in the production of critical ideas and the emergence of creative insights.

Before designing the main experiment two pilot studies were conducted with the intentions are given below:

- Testing adequacy of research instruments
- Assessing whether or not the research methods are realistic and feasible
- Establishing whether the sampling frame and technique are effective
- Identifying logistical problems which might occur using proposed methods
- Getting used to data collection, data analysis and data interpretation methods

The first pilot study covered feasibility test and limitations of Social Paradigm Belief Inventory (SPBI). A sample of 42 students who enrolled Izmir Institute of Technology, Department of Architecture and Department of Mechanical Engineering voluntarily participated in the pilot study. They were asked to report whether there are statements hard to grasp meaning after completing the inventory. None of the 42 students reported negative feedback. Yet, one student reported that he would like to write his own statement in one inventory item. This report was not taken into account as the inventory is forced a choice. It was expected that to complete the inventory in maximum 45 minutes, but after observations, it was seen that 45 minutes is quite low as the longest session was 1 hour 37 minutes.

The second pilot study covered to test adequacy, feasibility and limitations of both SPBI, think aloud protocol and linkography. Two students, who enrolled Izmir Institute of Technology, Department of Architecture and Department voluntarily participated in the second pilot study. One scored 2.44 points at SPBI with 15 Relativistic answers, and the other scored 2.63 with 18 Dialectical answers. Participants asked to think aloud during designing the first project was given in spring semester both at class and home and record the sessions. Before performing the task, the instructions of how to execute think-aloud method was explained to them with examples and the first sessions conducted with the author. At the end of a project deadline, in total 17 hours, 37 minutes think aloud data was collected. However, only five hours of these data transcribed and segmented, because it was observed that linking long and disunited think aloud sessions are not feasible to work with. Thus, it was decided to conduct the main experiment as a unified, time-limited design session.

The main experiment designed according to conclusions of the two pilot studies. At the main experiment, the inventory was sent to participants by e-mails and collected next day in order not to hinder their daily responsibilities. As indicated above, it was decided to conduct the main experiment in a time limit, thus the design sessions limited to 45 minutes. All participant was given the same problem. Because of the participants were varied novices to experienced, a general and easy design problem was given in order to secure that all participants can solve the given problem with the skills gained in first grade. Thus, first-grade students weren’t allowed to participate in the study, as they haven’t completed the Basic Design course yet. The given design brief is below:

Task:

Please design a seating unit which will be placed along the seafront of İzmir (e.g. Kordon).

Methodology: Freehand Sketches andThink Aloud

You have to verbalize all your thoughts during forty-five (45) minutes design session which will be recorded with a video camera and voice recorder in order to analyse the session. You are also expected to solve the design problem was given in design brief by using free-hand sketches.

Materials: Drawing papers, coloured and lead pencils

Time: Forty-five (45) minutes

In order to make the environmental conditions same for all participants, each of them conducted the experiment in the same room, with the same materials. Ten A3 papers, a coloured pencil set tin of 36 and a lead pencil set were provided. All participants were alone with the experimenter during executing the design task.

A total of twenty-five students, fifteen males and ten females, voluntarily participated in the research. Each student respondent in this study was answered demographic questions concerning age, gender and grade. The participants varied in age from 20 to 27, with a mean of 21.52 years. All participants were undergraduate students of Izmir Institute of Technology, Department of Architecture, Turkey. 32% of them was the 2nd grade, 24% of them was the 3rd grade and 44% of them was the 4th-grade students. The participants were recruited by advertisements that were posted on announcement boards at Faculty of Architecture.

Table 5. Gender and grade distributions of the participants

	Female	**Male**	**2nd Grade**	**3rd Grade**	**4th Grade**
Participants	10	15	8	6	11

Before performing the task, all participants were informed that they will be recorded with a video camera and voice recorder. They were explained how to execute think aloud method with examples and were notified experimenter is only allowed to warn them if they stop vocalize their thoughts.

3.1. Data Collection

Data was collected by employing two different methods. First of them was Social Paradigm Belief Inventory (SPBI), and was employed for to determine students' cognitive stages and scores. The second one, Think-aloud protocol, was used to elicit verbal reports of thought sequences as a source of data on students' thinking during design sessions.

3.1.1. Social Paradigm Belief Inventory

There are only 2 procedures to measure cognitive stages. First one is Complex Postformal Thought Questionnaire (CPTQ) developed by Sinnott (1989) which is constituted by 10 items that describe particular operations of postformal thought. However, there is any research on reliability and validity of CPTQ.

The second cognitive measurement is Social Paradigm Belief Inventory (SPBI) developed by Kramer et al. (1992). SPBI covers “everyday reasoning about behaviour in society, personal relationships and personality development, and problem-solving” (Blouin and McKelvie, 2012, p.42). SPBI is a 27-item, forced-choice inventory wherein subjects chose one of three statements; absolute, relativistic, or dialectical, with which they most agreed. Absolute statements are stands for Piaget’s formal operational thought and based on universally wrong or right judgements. In absolute thought, contradictions and changes are undesirable. Relativistic and Dialectical statements are not absolute statements. Relativistic statements based on the judgements were derived from personal experiences, knowledge and point of views (Kramer et al., 1992; Basseches, 1984). Thus, on the contrary to absolute thought, relativistic thinkers avoid predictions (Kramer et al., 1992). Dialectical statements based on the judgements derived by the evolution of contradictory thoughts and/or pre-judgements (Basseches, 1984), and “it is believed that perspectives always grow and change” (Vanier and Searight, 2013, p.50). Examples of each paradigm are given below (Kramer et al., 1992):

> *Absolute Statement:* You can know a person completely. This is because after a long enough time a person's real self-emerges; allowing you to see what makes him or her tick.
>
> *Relativistic Statement:* You cannot know a person completely. This is because a person seems different all the time depending on what part of him or her you look at.
>
> *Dialectic Statement:* You cannot know a person completely. This is because getting to know a person in a particular way means not getting to know him or her in some other way.

Since all the participants of this study were Turkish native speakers and there is no published Turkish version of SPBI, it was translated to Turkish by author and reviewed and corrected by a certified English translator and interpreter and a Turkish linguist. The example's, which was given above, Turkish translation is given below:

> *Absolute Statement:* Yeterince birlikte zaman geçirmişseniz bir insanı tamamen tanıyabilirsiniz. Çünkü o kişinin gerçek kimliği belirginleşmiştir ve bu da sizin o kişiyi etkileyen şeylerin ne olduğunu öğrenmenizi sağlar.
>
> *Relativistic Statement:* Bir insanı tam anlamıyla tanıyamazsınız, çünkü o insanla ilgili görüşünüz kendi bakış açınızın da etkisi altındadır.
>
> *Dialectic Statement:* Bir insanı tam anlamıyla tanıyamazsınız çünkü insanların farklı farklı yönleri vardır ve tüm yönlerinin bilinmesi imkansızdır.

To get final scores, for every absolute statement participant receive one point, for every relativistic statement participant receive two points, and for every dialectical statement, the participant receives three points. Scores are then summed for a total score and the final divided by 27 to find the average. So, to be a pure absolute thinker or dialectical thinker participant should have an average one point or an average three points which means answering all items at same statement type. This is also applicable to relativistic thinking with one difference; to state that participant is a pure relativistic thinker, looking at the average score is insufficient and average two points not always indicate participant is a pure relativistic thinker, so the answers should be all relativistic to conclude that. In all other cases, average scores indicate that in which frequency participant employs a thinking level. For example, when a participant gets 1.19 points, the researcher can say that participant tends to think absolute, and therefore she/he is an absolute thinker. So, average scores are variated 1 to 3 points scale. Also, SPBI scores are ipsative, in other words getting high scores on absolute thinking means getting low scores on relativistic and dialectical thinking (Vanier and Searight, 2013).

Kramer et al. (1992) report that the scale was showed internal consistencies ranging from .60 to .84 (M = .72; SD = .11), which means SPBI has a good test-retest reliability.

3.1.2. Think - aloud Protocols and Design Sessions

According to Anders Ericsson (2006), “protocol analysis is a rigorous methodology for eliciting verbal reports of thought sequences as a valid source data on thinking.” As is also understood from the definition of protocol analysis, this methodology is based on individuals’ self-reports. According to the self-report types, protocol analyses can be group under two titles; retrospective protocol analysis and concurrent protocol analysis.

Retrospective protocol analysis based on introspective self-reports and individual narrates her/his thoughts after the fact. Early methods of gathering introspective data were mostly based on questionnaires and structured interviews (Ericsson, 1998). Yet, as Ericsson (1998) stated since the researcher has no other empirical data to evaluate the validity of self-reports, data analysis falls short and might lead false conclusions. Besides this fact, because of remembering the thought accurately is almost impossible, using retrospective protocol analysis is accepted as unreliable. With a small self-experiment, one can verify the memory problem on this issue by trying to draw a particular object, let’s say 1 TL coin, and then compare the drawing with the actual one. The experimenter will see how different the drawing than the actual coin. This problem arises because of how the brain works; since our brains have not any hard memories like as computers, it doesn’t copy the actual image of the object but a representation of it which is constituted by patterns to recognize it next time the individual sees it. In the context of thoughts, the problem becomes more complicated as every thought is unique and it is more complicated to create a representation and pattern for every single one. So, thoughts are more vulnerable to deformation, distortion and fall into oblivion. This particular problem also makes crosschecking impossible. Thus, introspection has been dismissed and lost its scientific validity mostly. Yet, like as in the psychological case, introspection still in use when there are no more valid methods.

The other type of protocol analysis, also known as concurrent protocol analysis, based on real-time self-reports to overcome retrospective protocol analysis' reliability problem. Real-time reports are acquired by think-aloud protocols and are recorded by media tools such as video and voice recorders. By this way, the researcher also gathers other empirical data to evaluate the validity of self-reports.

The think-aloud protocol is accepted as a valid method for design research to collect data on the thought process of a subject is asked to verbalize their thoughts while completing a defined task. The think-aloud protocol is a very direct method to gather raw data of problem-solving and reasoning processes and frequently being in use by researchers to understand cognitive processes of designing (Someren et al., 1994; Ericsson, 1998; Gursoy, 2010). According to Goldschmidt (2014), "Real-time reports come much closer to representing thought processes than introspective reports do." (p. 27) Although, because the time passes by between the thinking and verbalizing is short these problems become minimum, real-time verbal reports still have some deformation and distortion problems. Indeed, even though real-time verbal reports are more reliable, they also have some deficiencies. Peter Lloyd and his colleagues (1995) start their criticism highlighting these deficiencies by exampling dyslexia, and how it is hard to assign words to thoughts at this disorder. They continuous as:

> If dyslexia could be considered as a filter between thought and speech, then we might hypothesize that such a filter, to a greater or lesser extent, exists in everyone. That is to say, the thought is always mediated and sometimes offset, by channels of communication formed by constitution and experience. A central problem for protocol analysis as a research tool is to determine just how much these channels of communication affect the thought preceding the communication. Generally the paradigms of information processing, and particularly the psychological research area of problem solving assume that the affect of communication channels on problem solving thought is minimal. This may well be true for 'conventional' problem solving tasks but the relatively recent application of protocol analysis to design tasks has again brought the assumptions that underlie protocol analysis under scrutiny. (Lloyd et al, 1995, p.238)

As it can be inferred from the text above, the main criticism about the reliability of verbal data is the idea of manipulation, deformation and distortion of thoughts while verbalizing due to several limitations like disorders and language shortcomings. Protocol analysis is also criticized because verbalizing the thoughts during problem-solving process might alter the process itself and so it cannot be able to grasp actual and natural process. Besides this two main criticism, it is also reprehended to be weak in capturing non-verbal data.

Despite all these criticisms against protocol analysis, it still is beyond the traditional methods of gathering information of thinking during problem-solving (Ericsson, 2006) and is accepted as very valuable on capturing design thinking even if it is highly specific (Cross, 2006). Furthermore, because currently there is no other direct way to reach thoughts during the action, protocol analysis and real-time verbal reports as data are still commonly in use in design thinking research.

To collect data with Think-aloud protocol, the subject should verbalize whatever crosses her/his mind while performing the given task in a timeframe. Meanwhile, the researcher should record the activity by appropriate devices without interrupting the focus of the subject. However, with a load of cognitive activities, the subject may tend to stop speaking or may start to mutter; in such circumstances, the researcher should interfere and encourage the subject to speak or to be loud with a minimum amount of words (Someren et al., 1994). This issue, among capturing non-verbal thought processes and lack of effective verbalization of thoughts, is one of the main criticism towards Think-aloud protocols (Lloyd et al., 1995; Cross, 2001). Despite the arguments against Think-aloud protocols by being grounded on valid reasons, as mentioned above, the method is still the best option for collecting direct data on thinking process.

To conduct this method researcher should complete these five tasks:

1. Framing a problem
2. Recording problem-solving process
3. Transcription of recordings
4. Segmentation and coding
5. Analysis of coded protocol

The first step, framing a problem, is closely connected to the aim of research. If a researcher wants to collect data of the well-defined problem-solving process, problem brief should be framed according to it, and similarly, the researcher may want to collect data of ill-defined problem-solving process like in almost all design problems or even data of problem finding process itself. So, the researcher should be aware of how brief might lead the participants and should ask them to solve problems which could provide useful data for her/his research.

During the problem-solving sessions, the researcher needs to record verbal data by media tools. To have other empirical data video recordings is commonly in use besides voice recordings. Using video recordings also provide materials to crosschecking whether or not participant doing activities what she/he is verbalizing or leaves it behind as a thought.

Transcription of recordings is the step that converting the voice records to texts. At this step, the quality of voice records play an important role as participants tend to lower their voices while focusing the task, and it might be hard to decipher if the recording quality low. That is why setting a second media recording might be useful to data vetting.

According to John Gero and Thomas Mc Neill (1998), because of protocol data is quite unstructured and can be quite abundant, the researcher needs to establish a framework and segmentation should be done according to it. Segmentation is parsing the transcripts into phrases. These phrases are lines of reasoning and sequences of design decisions. The example below shows an excerpt of a protocol and its segments.

Utterance 42. and to make them fixed on the ground there should be some linkups

Utterance 43. either it will be heavy

Utterance 44. or it will be fixed by some fasteners like stakes

Utterance 45. or it might be directly fixed to concrete

Utterance 46. steel screws can be used to mount it

After segmentation researcher has a structured data to analysis. In this thesis, data analysis was done by employing Linkography. Thus, to be used in Linkography, the data acquired by think-aloud protocols parsed and segmented to design moves.

3.2. Data Analyses

Segmentation of the data was conducted upon the description in Think-aloud Protocols and Design sessions chapter in this thesis. Then, interrelations of design moves were determined to form links between them. The final linkographs and general statistics of segments, which are link index and entropies of forelinks, backlinks and horizontal links, acquired with the help of LINKOgrapher software developed by Morteza Pourmohamadi and Gero (2011). According to Goldschmidt (2014), one of the indicators of creativity is “critical moves” (CM), which are rich in links. When twenty-five design sessions were evaluated, CM threshold was determined as 6 for the overall participants. To correlate link indexes and linkographic entropies with SPBI scores Pearson's correlation coefficient method was employed by the aid of SPSS v13 software.

For the syntactic analysis, every single participants’ critical move thresholds are calculated and for getting a rich data to analyse, the CM networks which are rich in links are chosen. Then, for every single chosen CM network, the constituent design moves are coded according to Function – Behaviour – Structure (FBS) model and Information Categories (IC) coding scheme. The design transformation types (e.g. analyses, synthesis and formulation) of the design moves are identified, and the related thinking types are determined. It is also determined that whether or not the design moves caused a conceptual shift or conceptual transformation. Finally, the obtained results are used for detecting the relationship patterns between the transformation types and postformal thinking types by applying inductive reasoning.

3.2.1. Linkographic Studies

In design domain, it is hard to explicitly trace creativity in the design process as it is endogenous. Thus, to assess creativity, researchers should use a roundabout way by generating measurements to investigate the structure of problem-solving processes to ascertain patterns indicate creativity. In design thinking research, protocol studies are the common approaches to analyse the structure of design processes. Although there are numerous criticisms on protocol analysis’ reliability (Lloyd et al., 1995; Cross, 2001), according to many well-known researchers, such as Nigel Cross, John S. Gero, K. Anders Ericsson, Gabriela Goldschmidt and Herbert A. Simon, it is still the most effective method to assess cognitive process during problem solving and is the core component of Linkography method.

According to Van der Lugt (2003), pioneers of Linkograph could be accepted as the early graphical representations of problem-solving processes, such as “Problem Behaviour Graphs” (Ericsson and Simon, 1984; Newell and Simon, 1972), and “Decision Trees” (Dwarakanath and Blessing, 1996). Yet, because both they are required to be retrospective, which causes a fundamental problem of assessing reliable data, they are unsuitable for analysing idea generation processes.

On the contrary of decision trees and problem behaviour graphs, linkography, directly based on concurrent protocol analysis by using the think-aloud method and “addresses the ways in which designers make connections with previously generated design information by recording the links among design moves.” (Van der Lugt, 2001, p. 60) Because of this approach, Linkography is more useful on graphically represent of problem-solving processes than its pioneers.

To understand the Linkography method thoroughly, one should look at its core components.

3.2.1.1. Linkography as an Assessing Technique

Linkography is a method to analyse designers' cognitive activities by graphically representing the moves and the links between them to reveal structural patterns of design reasoning. Goldschmidt, developer of the Linkography, established this method with the notion of idea generation process, within the design process, should have been embodied of linked sub-ideas which are gained earlier in the process (Goldschmidt, 2014). Goldschmidt calls these sub-ideas as design moves, and defines as "a step, an act, an operation that transforms the design situation somewhat relative to the state it was in before that move." (2014, p.42). According to Goldschmidt’s technique, design moves are obtained by segmenting protocols that are recorded during think-aloud sessions. Then, to construct a linkograph, the links between related design moves are pinpointed. By this way, it can be achieved to a graphical representation of a design session. As an example, P22's partial segmentation is given below:

M6: I guess… My concept will be nature, as seaside connote nature for me

M7: that's why it [seating unit] shouldn't have orthogonal forms like I am drawing at the moment

M8: It should have some organic forms like we can encounter in nature

M9: Indeed, just today we researched on is there any orthogonal, but organic forms in nature

M10: It can be something like a honeycomb. This is the simplest one I can think now

M11: Linear like this (pointing the drawing)… By this way, it can be self-supportive without a need for other structure

M12: Also, It can repeat itself and enlarge

M13: I mean… when we combine the repetitive modules, we can create an organic shape

M14: When we inspect a leaf we can see how linear forms can create organic forms, so squares can create organic forms… I can use this…

M15: Or… I can use triangles as the base element of my design

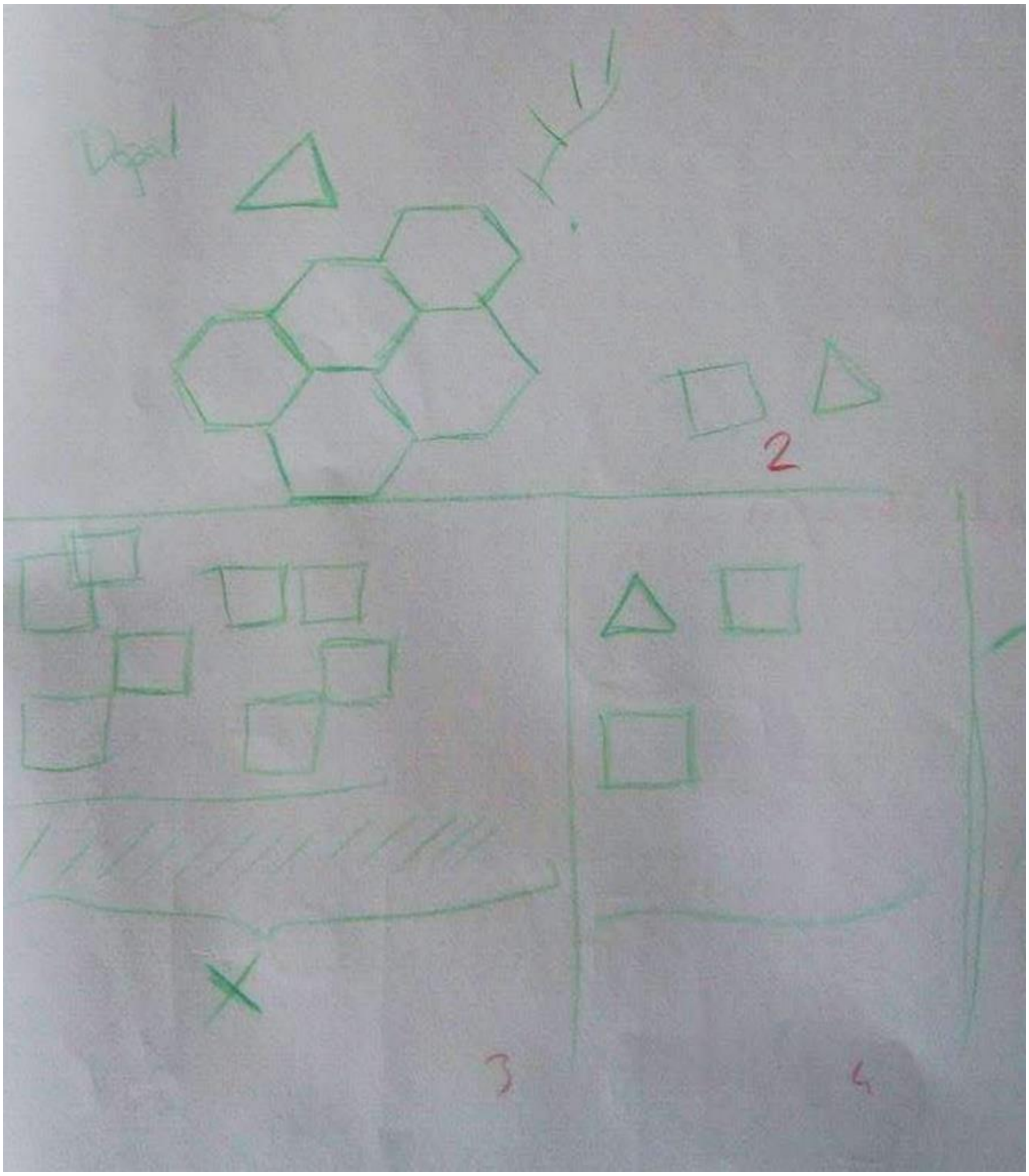

Figure 10. Sketch of the P22

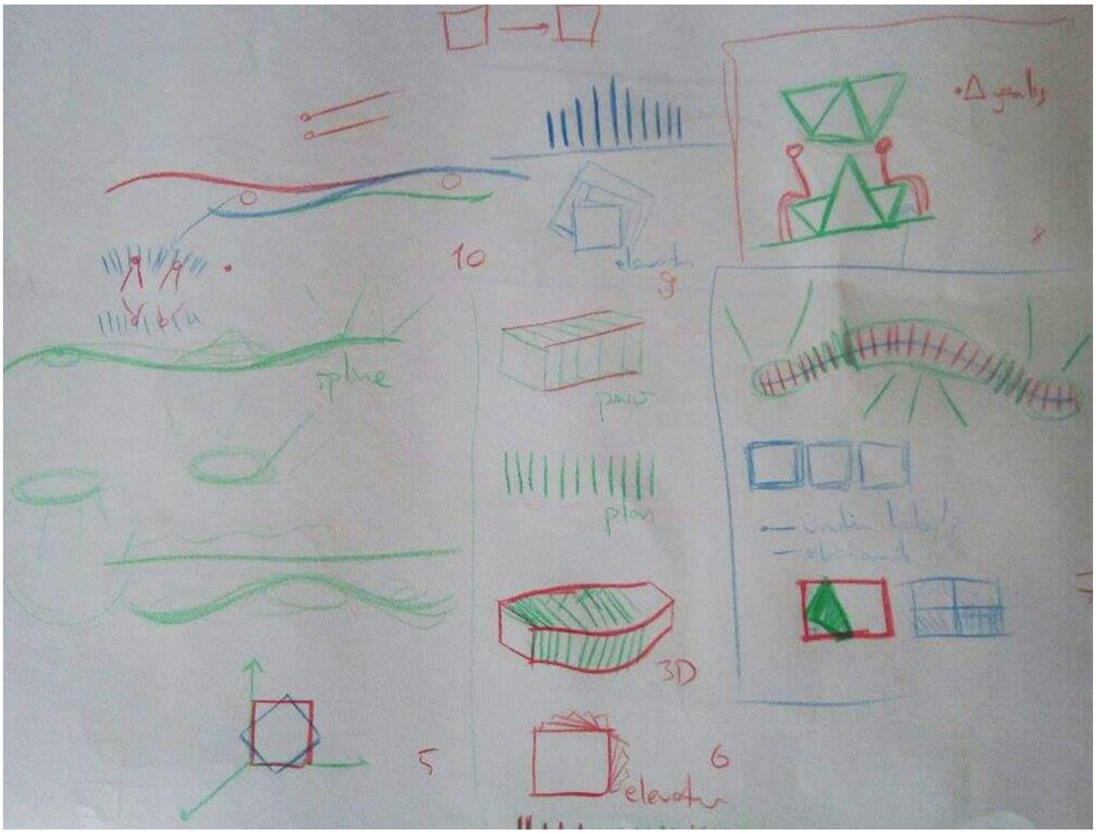

Figure 11. Sketch of the P22

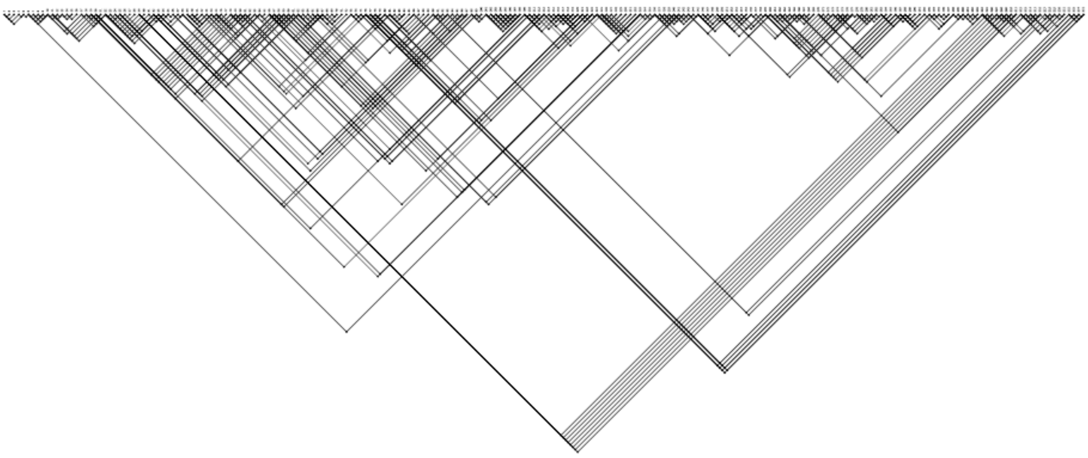

Figure 12. Linkograph of P22

In segmentation process, the sequence of links is not important, but the contents of moves are the determiners. Thus, a design move can be linked to distant primogenitor or posterity ones, as well as the ones next to it. Furthermore, if there is no connection to other design moves it can be left alone or if there are more than one connections it can be linked to several moves. *Backlinks* are the links of the moves that connect to previous moves, and represent by "<". *Forelinks*, on the contrary, are the links of moves that connect to subsequent moves, and represent by "<".*Orphan moves* are the moves have no links. If the moves have either forelinks or backlinks, they are called as *Unidirectional moves*, and represented by Udir> or <Udir. If the moves have both forelinks and backlinks, they are called as *Bidirectional moves* and represented by <Udir>. Besides these five definitions, Goldschmidt (2014) also describes one more type of move, called as *Critical move,* which is very important to determine creativity in design processes, because these moves are the ones which are forming a large number of links, and represented by CM.

Goldschmidt (2014) also defines different geometrical patterns these links form. *Chunk* is a link pattern "is graphically distinct as discernible triangle" (Goldschmidt, 2014, p. 62). *Sawtoothtrack* is a link pattern is graphically distinct as discernible zigzag. *Web* "is formed when a large number of links are generated among a relatively small number of moves." (Goldschmidt, 2014, p. 64) Please see Figure 13 for their graphical representations in a linkograph.

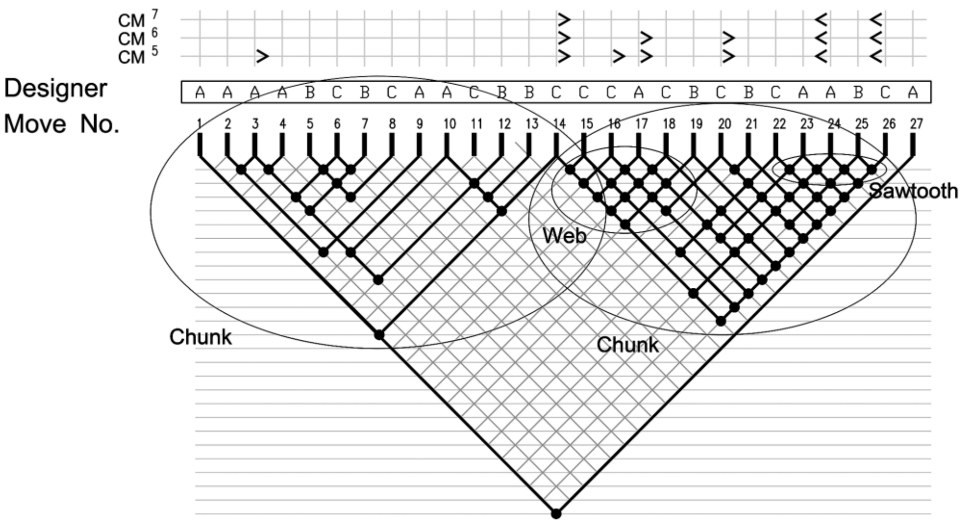

Figure 13. Link patterns (Source: Goldschmidt, 2014, p. 63)

3.2.1.2. Backlinks and Forelinks

A backlink is a descended of an anterior one. So, to establish whether or not a link is a backlink, the researcher should look its direction (Figure 14). If the move refers to a previous one then its link is a backlink. As an example, if the 45th move refers or rooted to the 12th move, then it creates a backlink from 45th move to 12th move and represented as <45.

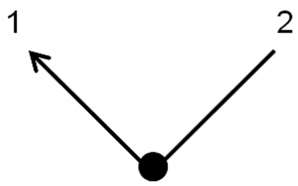

Figure 14. Backlink (Source: Goldschmidt, 2014, p. 49)

Every move which has a backlink is also connected to its anterior with a forelink (Figure 15). If we explain it in the same example, since the 45th move has a backlink, the 12th move should have a forelink which connects it 45th move and therefore represented as >12. Here, the critical detail is when the 12th move was established, the 45th move has not been created yet, thus the forelink between 12th and 45th moves is a virtual link and only can be detected after the 45th move is established.

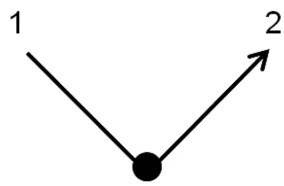

Figure 15. Forelink (Source: Goldschmidt, 2014, p. 49)

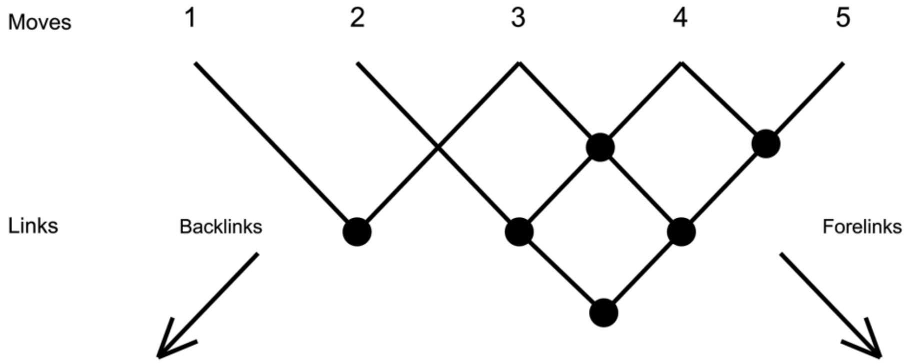

Figure 16. Backlinks and Forelinks (Source: Goldschmidt, 2014, p. 49)

According to Goldschmidt (2014), the benefit of distinguishing forelinks and backlinks (Figure 16) is in determining the proposals and the responses to these proposals during the design session. In other words, the moves have forelinks are the proposals, and the moves which have backlinks are the responses. Here, the important part is that if the move has many forelinks, it means that move is prolific in the idea generation process and therefore can be assumed as original, appropriate and creative. Likewise, the move with many backlinks is kind of proofs that "a good fit exists between the current move and previous work, and that no apparent contradictions, mismatches, or other negative consequences are evident in the design process." (Goldschmidt, 2014, p.50)

3.2.1.3. Orphan, Unidirectional and Bidirectional Moves

In some cases, design moves cannot generate any links. Goldschmidt (2014) calls this kind of moves as Orphan moves. These infertile moves are unsuccessful design proposals and having many of orphan moves are indicators of a poor design session and uncreativity. As you see in Figure 17, which is a part of a design session's linkograph, the 35th move has no links, therefore it is an orphan move.

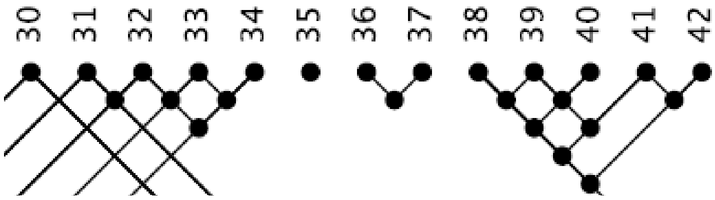

Figure 17. Orphan move (35th move)

If a move is not an orphan one, then it should be either bidirectional or unidirectional move (Goldschmidt, 2014). In the case of a move only has forelinks or backlinks, then it is a unidirectional move. In Figure 18, it can be seen 1st, 8th and 10th moves have only forelinks and the 23rd move has only backlinks. Therefore, these moves are unidirectional.

On the contrary, the vast majority of the moves in design sessions are bidirectional, which have both forelinks and backlinks (Goldschmidt, 2014).In Figure 18, it can be seen that, except the 1st, 8th 10th, and 23rd moves, all the other moves have both types of links and therefore bidirectional.

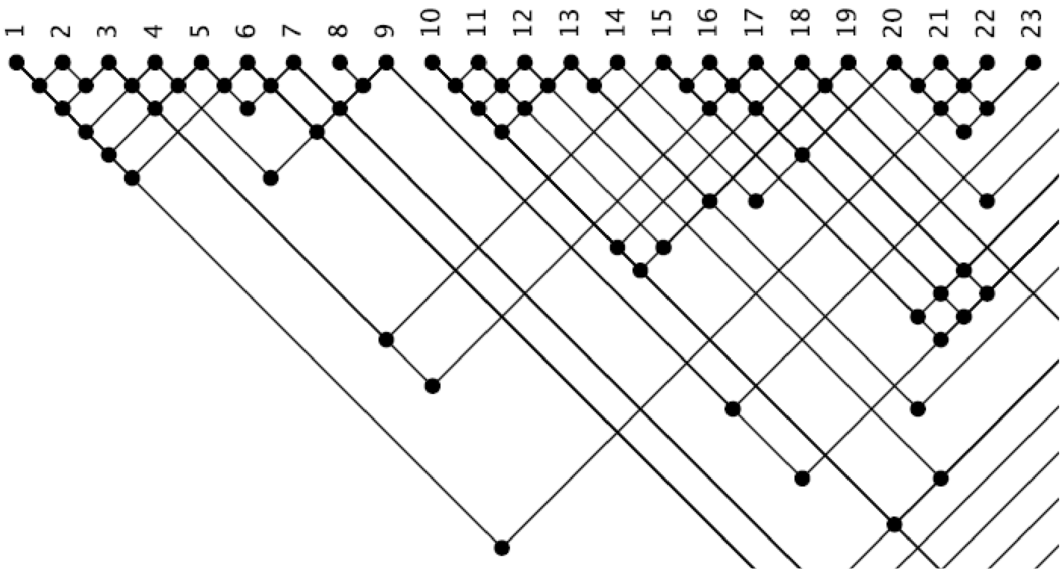

Figure 18. Bidirectional and unidirectional moves

3.2.1.4. Critical Moves

Critical moves (CMs) are the design moves which outnumbering majority of the moves in a design session on forming links. These moves are critical because, as a move, they lead designer to produce more links and new moves which might be also critical ones. Thus, critical moves have significant roles in determining creativity, because these moves are the indicators of quality of idea generation and problem-solving process (Goldschmidt, 2014; van der Lugt, 2001). As highlighted before, if a move is able to create so many links, it is a proof of that the move well-fits to the problem-solving process, and the signifier of originality and appropriateness.

According to Goldschmidt (2014), to qualify the critical moves, the researcher should examine “the grain of the analysis, or the overall number of links” (p.58). However, grains and/or an overall number of links of a design session vary according to the overall quality of design session. Thus, where forming 4 links is critical for one session, for other session forming 8 links might be critical. “The threshold number for qualifying links as critical is therefore flexible” (Goldschmidt, 2014, p.58). Therefore, the threshold also should be indicated when speaking of critical moves. So, the representation became as CMt.

Even if there is no consensus on what threshold should be, according to Goldschmidt (2014), design session’s 10% to 12% CMs of the total number of the moves could be accepted as the threshold. Therefore, logically, where multiple design sessions are evaluated, the threshold could be determined as close to 10% to 12% CMs of mean of the total number of the moves of all design sessions.

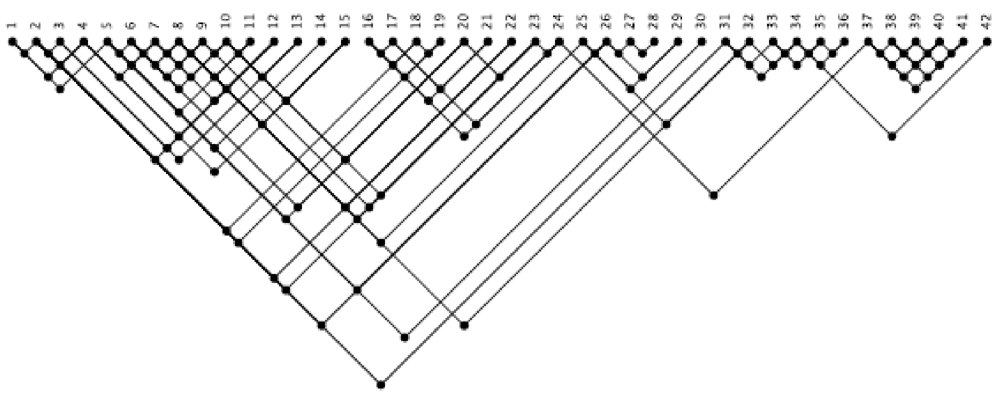

Figure 19. A linkograph of a short design session

The linkograph of a short design session which can be seen in Figure 19, has six <CM5, as moves 2, 5, 6, 8, 10 and 16; has three <CM6, moves 2, 5 and 8; likewise has three <CM6, moves 2, 5 and 8; has two CM5>s, which are moves 12 and 23, and none CM6> or CM7>. Also, there is no <CMs> in this design session. So when we calculate the percentages, CM5s are equal to %19.04 and CM6s are equal %7.14. In this case, because of proximity to %10, the threshold can be determined as CM6 (please see Table 6).

Table 6. Critical moves of a design session which is given in Figure 14

Moves	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
<CM	3	9	2	3	7	5	4	8	2	5	0	0	0	0
CM>	0	1	1	1	1	1	3	2	3	3	3	5	2	1
Moves	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
<CM	0	5	2	1	0	1	0	0	1	1	3	2	1	0
CM>	3	0	1	2	3	3	2	2	5	3	1	3	1	1
Moves	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**
<CM	0	0	3	1	2	3	1	0	4	3	2	1	0	0
CM>	2	1	1	3	1	3	2	2	1	1	2	3	4	1

3.2.1.5. Link Index

Link index is the ratio between the number of links and the number of moves that generate them in a given design session (Goldschmidt, 1992). Thus, link index is closely connected to a number of design moves. Where numbers of design moves are higher, link index will be higher too. Link index value, prima facie, can be assumed as a kind of pre-indicator of the amount of linking activity, which also an indicator of the designer’s effort to achieve a synthesis (Goldschmidt,2014). Yet, as Goldschmidt (2014) highlighted, this kind of early assumptions may lead to a wrong conclusion because, in design sessions, it is highly common to encounter that “many repetitions or many attempts to explore alternative ideas with little continuity among them“ (Goldschmidt, 2014, p.70). Thus, when accepting Link index is an indicator, it is highly recommended that being cautious and verifying the results carefully. Yet, when link index is carefully used, it is also a good indicator of creativity and idea generation quality (Goldschmidt and Tatsa, 2005). Because, "the more meaningful and helpful the idea, the denser the network of links it is involved in." (Goldschmidt and Tatsa, 2005, p.605) In this study, link index accepted as a variable as the density of productiveness to correlate post-formal thinking levels and creativity.

3.2.1.6. Chunk

A chunk is a group of links which are only and solely connected to each other and graphically looks like a triangle. These connections could be either loose or dense. According to Goldschmidt (2014), frequently, chunks are embodied by a dozen to two dozen moves which are enquiries of related investigations. Therefore, "a chunk stands for a cross-examination of relevant properties, related questions, and possible implications of a design issue." (Goldschmidt, 2014, p.63) Whenever designer starts to examine another sub-problem, the cycle ends, and a new cycle begins as a new chunk. So, one can read from the linkograph when the designer stops on working on the sub-problem and alter her focus on a new domain. Yet, of course, new sub-problem might has risen from the previous sub-problem and might have few links to the previous chunk, which can make to define chunks difficult. In those cases, "the processes they represent are less structured than processes with clear chunking, as there is no sequential treatment of clearly outlined issues." (Goldschmidt, 2014, p.64) So, one can read from the linkograph how much the design process was smooth and designer was good at re-structuring of ill-defined problem.

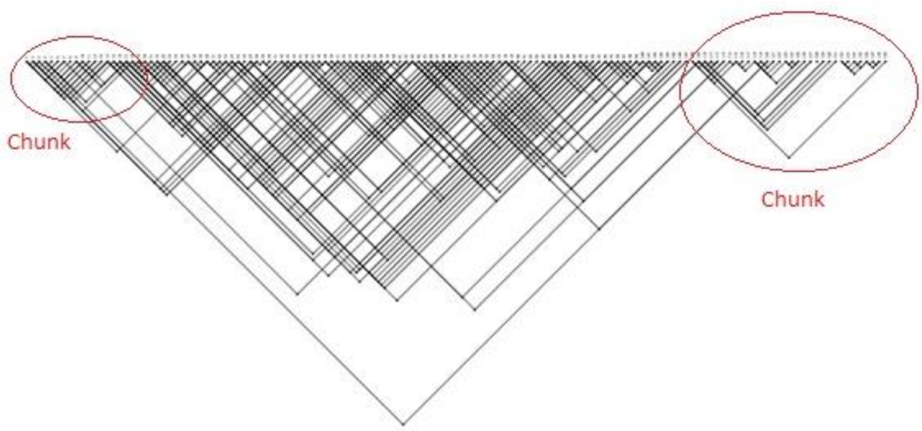

Figure 20**.** Chunks in a linkograph

As seen at Figure 20, the design session is mostly unstructured and tangled, thus it is hard to point out the chunks, yet the chunks at the beginning and at the end is clear which means the participant focused on sub-problems between the moves 1to 18 and 108 to 139.

3.2.1.7. Sawtooth Track

The Sawtooth track is a link pattern is graphically distinct as discernible zigzag (Figure 21). It is created by linking moves only anterior and posterior moves. When one sees that pattern, she/he can conclude that the thinking type at that point is quite formal and only depends on a strict question and its strict answer, like “should it be blue”, “yes, it should.”. Thus, there is no room for the following deliberation on the situation. Therefore, the moves in a sawtooth part cannot be critical moves and/or cannot be accepted as creative ideas. “When sawtooth tracks are not integral parts of a larger network but rather stand alone, we may conclude that at that point the designer is not engaged in a synthesis process but rather builds one observation or proposition upon another in a linear string, with no attempt to widen or deepen the investigation.” (Goldschmidt, 2014, p.65) According to Goldschmidt (2014), to being a sawtooth track, it should have at least 4 moves, but mostly sawtooth tracks have much more moves than four.

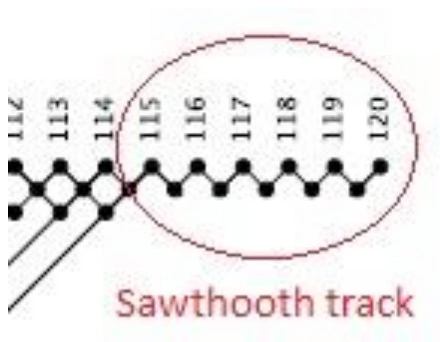

Figure 21. Sawtooth track in a linkograph

3.2.1.8. Web

"A *web* is formed when a large number of links are generated among a relatively small number of moves." (Goldschmidt, 2014, p. 64) Webs have denser interlinking, thus they tend to be smaller than chunks and are quite rare (Figure 22). Because of the dense interlinking "the highest link indexes are found in webs, which are defined a priori as high-link-density groups of moves." (Goldschmidt, 2014, p.69)

On the contrary of the sawtooth track, it can be inferred from webs that, at that certain design process period, designer intensively inspects a certain issue, and tries to clarify its aspects extensively. Therefore, it is common to observe critical moves at the beginnings and/or endings of webs (Goldschmidt, 2014).

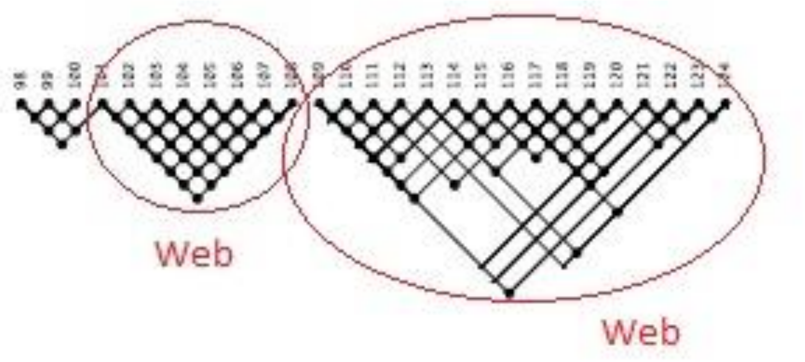

Figure 22. Web in a linkograph

3.2.2. Pearson's Correlation Coefficient Method

Pearson's correlation coefficient (r) is a measure of the strength of the association between the two variables. In this study, to determine the relations between creativity and post-formal thought, participants' SPBI scores and general statistics of their Linkographs compared and strength of the association between them examined by conducting Pearson's correlation coefficient method.

CHAPTER 4

RESULTS AND DISCUSSION: LINKS BETWEEN CREATIVITY AND POST-FORMAL THOUGHT

The first task's raw data obtained by SPBI. The objective of conducting SPBI was to determine participants' thinking styles and cognitive stages. Table 7 shows the detailed results of the SPBI scores.

Table 7. Details of SPBI results

SPBI	Score	Means of SPBI	Absolute	Relativistic	Dialectic
P1	55	2,037	5	16	6
P2	58	2,148	4	15	8
P3	58	2,148	3	17	7
P4	59	2,185	6	10	11
P5	60	2,222	3	15	9
P6	60	2,222	3	15	9
P7	60	2,222	6	9	12
P8	60	2,222	6	9	12
P9	61	2,259	1	18	8
P10	61	2,259	5	10	12
P11	62	2,296	1	17	9
P12	62	2,296	2	15	10
P13	63	2,333	1	16	10
P14	63	2,333	3	12	12
P15	63	2,333	3	12	12
P16	63	2,333	4	10	13
P17	64	2,370	-	17	10
P18	66	2,444	-	15	12
P19	66	2,444	4	7	16
P20	68	2,518	1	11	15
P21	68	2,518	1	11	15
P22	68	2,518	-	13	14
P23	69	2,555	2	8	17
P24	70	2,592	-	11	16
P25	71	2,629	1	8	18

When Table 7 is examined, it can be seen that all participants used relativistic and dialectical thinking in diversified frequencies during the Task1, and the majority of them used all thinking types, formal, relativistic and dialectical. As formal thinking is similar to convergent thinking and the post-formal thinking similar to divergent thinking, and also it is proven that creative thinking involves both divergent and convergent thinking (Cropley, 2006; Goldschmidt, 2014; van de Lugh, 2001), it can be expected that during solving an ill-defined problem, solvers who reached to the dialectical thinking level may apply formal, relativistic and dialectical thinking. As nature of design problems involves a different kind of design variables and knowledge domains, successfully solving one might depend on applying all three thinking types. Bill Hillier and Adrian Leaman (1976) highlight design problems' nature as: "Those who have been trained as designers will be using just such a code… which enables the designer to effect a translation from an individual, organisational and social needs to physical artefacts" (p.29).

Whatever the artefact being designed, the designer should deal with its technical aspects. During solving such technical sub-problems, designers seek one true solution in a closed system. Thus, during this phase designer may apply formal thinking. A part of protocol from the think-aloud session of Participant7 is given as an example below (see Figure 23 for the linkograph):

M30: How much space a person occupies when sitting?

M31: I don't know the exact numbers [ergonomic values], but I assume 50 to 55 [cm].

M32: I will accept it as 55 [cm]

M33: It [seating unit] will be for four-person

M34: 4 times 55... It [the length] will be 220 [cm]

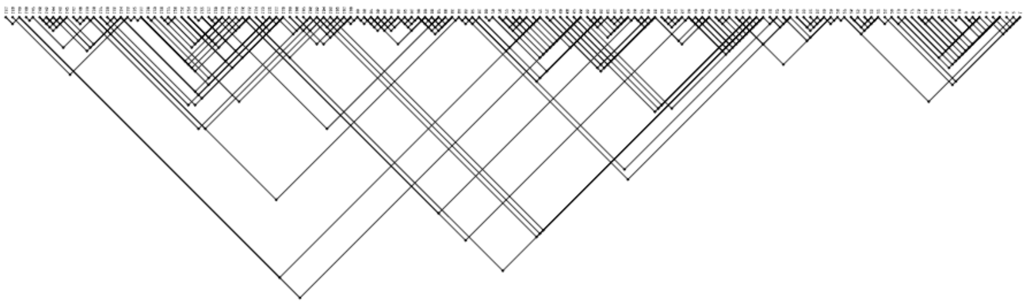

Figure 23. Linkograph of P7

As the artefacts have social representational values and meant to use by people from different backgrounds and preferences, designers should be aware of user diversity. Designing an artefact which has features against to the users' culture, moral principles or simply to daily life preferences might end up with failed design proposals. In such cases, designers may apply relativistic thinking to ensure that they address the majority of personal preferences. An example of P13's protocol (see Figure 24 for the linkograph):

> *M10:* When we examine the seating activity at Kordon… we can say that people prefer to sit as in groups
>
> *M11:* They don't prefer to sit alone, but with friends
>
> *M12:* That's why I think people wouldn't use single seating units
>
> *M13:* How it [seating unit] can be… a seating unit allows gathering?
>
> *M14:* Maybe… if a circular-like shaped seating unit would be designed, people could use it collectively [as groups]

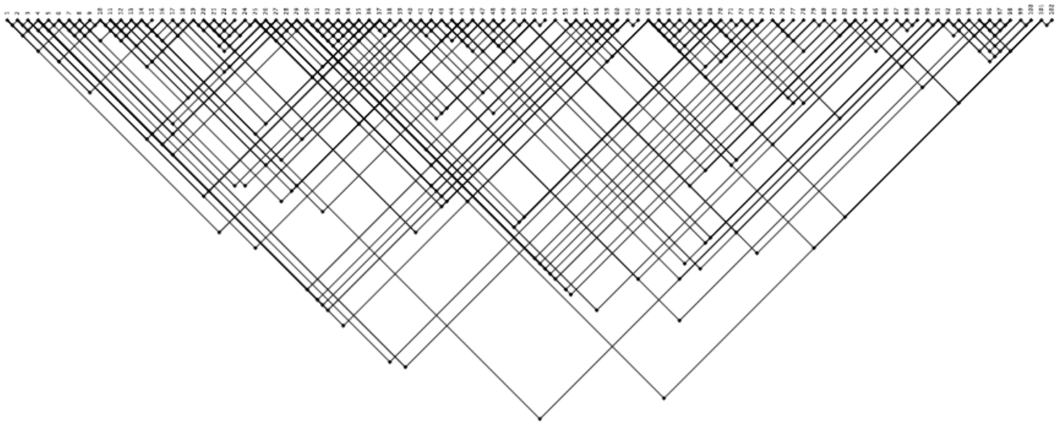

Figure 24. Linkograph of P13

According to Akin (1979), the design process is “the constant generation of new task goals and redefinition of task constraints” (p.116). Being aware of that the diversity can occur in any way, might cause conflicts, and everything is in a constant change may yield a person to think holistically and dialectically. During the design process, determining the conflicts, and attempts of reconciling these may lead the designer to come up with novel solutions by forcing her to break-open the commons. To do so, she/he may approach the ill-defined problem in peculiar ways. In such cases, designers might apply dialectical thinking. A part of P24’s protocol is given as an example below (see Figure 25 for the linkograph):

M31: I prefer to disconnect it [seating unit] from the road

M32: But also I don’t prefer to disconnect it [seating unit]

M33: Because if I want to be alone, I wouldn’t like to see people who are passing by

M34: but, (…) time to time there is a need to see other people, as passive contacts. As if such a need happens…

(…)

M35: I am unsettled about… Should the plans’ shape be more sharp or organic?

M36: Organic sounds more appropriate.

M37: But making it sharp might has other advantages

M38: I am going to decide during the process, I might use both of them.

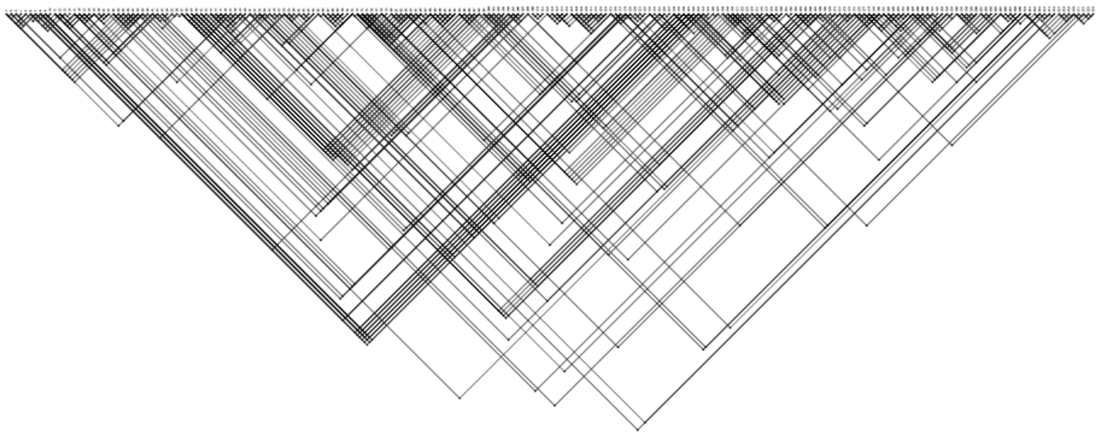

Figure 25. Linkograph of P24

According to Schön (1983, p.129), “problem of design problems” is finding the problem. Similarly, Cross (2006) states that “designing involves ‘finding’ appropriate problems, as well as ‘solving’ them, and includes substantial activity in problem structuring and formulating, rather than merely accepting the ‘problem as given’” (p.77). As seen from the examples from protocols above, all three type of thinking styles helps the designer to re-structure the problem by identifying its sub-problems from different knowledge domains, as well as solving them. Yet, the designer should link the sub-solutions into one design proposal. Thus, the success of the design proposal also depends on the success of interrelating the sub-solutions.

This chapter presents two analyses. The first analysis focuses on the quantitative relations between postformal thinking and creativity by correlating the SPBI scores and Linkographic entropies of participants. The second analysis focuses on qualitative relations by adopting syntactic and network analyses.

4.1. Quantitative Analysis of Protocols: Post-formal Thinking and Linkographic Entropies

In order to examine the linking activity, in total 663 minutes think aloud recordings transcribed into 228 pages raw data and analysed. The findings are presented in Table 8 as linkographic entropies.

Table 8. Details of design moves results

	Total Moves	Total Links	Link Index	Fore Links	Back Links	Horizontal Links
P1	59	114	1,93	20,114	21,858	9,585
P2	42	85	2,02	16,251	20,712	9,632
P3	103	207	2,01	25,474	28,634	10,283
P4	65	119	1.83	17,940	23,281	9,323
P5	36	74	2.06	15,233	16,929	11,568
P6	100	206	2,06	25,167	31,614	8,770
P7	151	314	2,08	31,860	38,076	9,048
P8	67	139	2,07	22,478	26,179	8,962
P9	128	281	2,20	31,021	30,789	12,896
P10	149	324	2,17	32,630	40,348	9,869
P11	120	278	2,32	31,914	35,564	11,348
P12	127	295	2,32	27,826	37,278	13,008
P13	102	275	2,70	30,883	38,389	14,064
P14	84	206	2.45	27,751	31,163	14,203
P15	82	195	2,38	26,972	28,520	11,835
P16	134	293	2,19	24,489	37,348	13,731
P17	120	294	2.45	31,019	36,156	13,470
P18	119	305	2,56	30,395	39,499	11,885
P19	120	273	2.28	32,377	35,916	11,786
P20	221	607	2,75	42,693	48,514	20,394
P21	146	400	2,74	40,163	43,892	12,429
P22	225	626	2,78	45,873	50,859	13,103
P23	139	412	2,96	32,217	44,289	17,207
P24	224	718	3,21	48,349	55,581	17,358
P25	135	464	3,44	39,376	48,485	15,934

Table 9. Correlation matrix of SPBI and Linkographic entropies

	SPBI Score	Link index	Absolute	Relativistic	Dialectic	Forelinks	Backlinks	Horizontal links	CMs	CM6+
SPBI Score	1	,923**	-,602**	-,446*	,879**	,822**	,858**	,779**	,508**	,858**
Link index	,923**	1	-,681**	-,291	,745**	,799**	,831**	,796**	,448*	,880**
Absolute	-,602**	-,681**	1	-,317	-,198	-,563**	-,513*	-,694**	-,350	-,536*
Relativistic	-,446*	-,291	-,317	1	-,818**	-,251	-,356	-,207	-,244	-,391
Dialectic	,879**	,745**	-,198	-,818**	1	,658**	,742**	,615**	,454*	,760**
Forelinks	,822**	,799**	-,563**	-,251	,658**	1	,947**	,644**	,463*	,855**
Backlinks	,858**	,831**	-,513*	-,356	,742**	,947**	1	,682**	,478*	,895**
Horizantal links	,779**	,796**	-,694**	-,207	,615**	,644**	,682**	1	,768**	,785**
CM	,508**	,448*	-,350	-,244	,454*	,463*	,478*	,768**	1	,591**
CM6+	,858**	,880**	-,536*	-,391	,760**	,855**	,895**	,785**	,591**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 9 shows the correlation matrix of the SPBI scores and the Linkographic entropies. As seen at the table, there is a positive linear relationship between the SPBI scores and link index. Also, as the SPBI score increase, the critical moves, which are the main indicators of creativity, tend to increase. In this study, the expected results were that the participants at post-formal thinking levels would obtain good link index and critical move scores, that is, that they would create more links in order to find creative solutions to ill-defined design problems. To investigate this, the participants' SPBI scores were compared with the link indexes and linkographic entropies.

4.1.1. Relations between SPBI Scores and Link Indexes

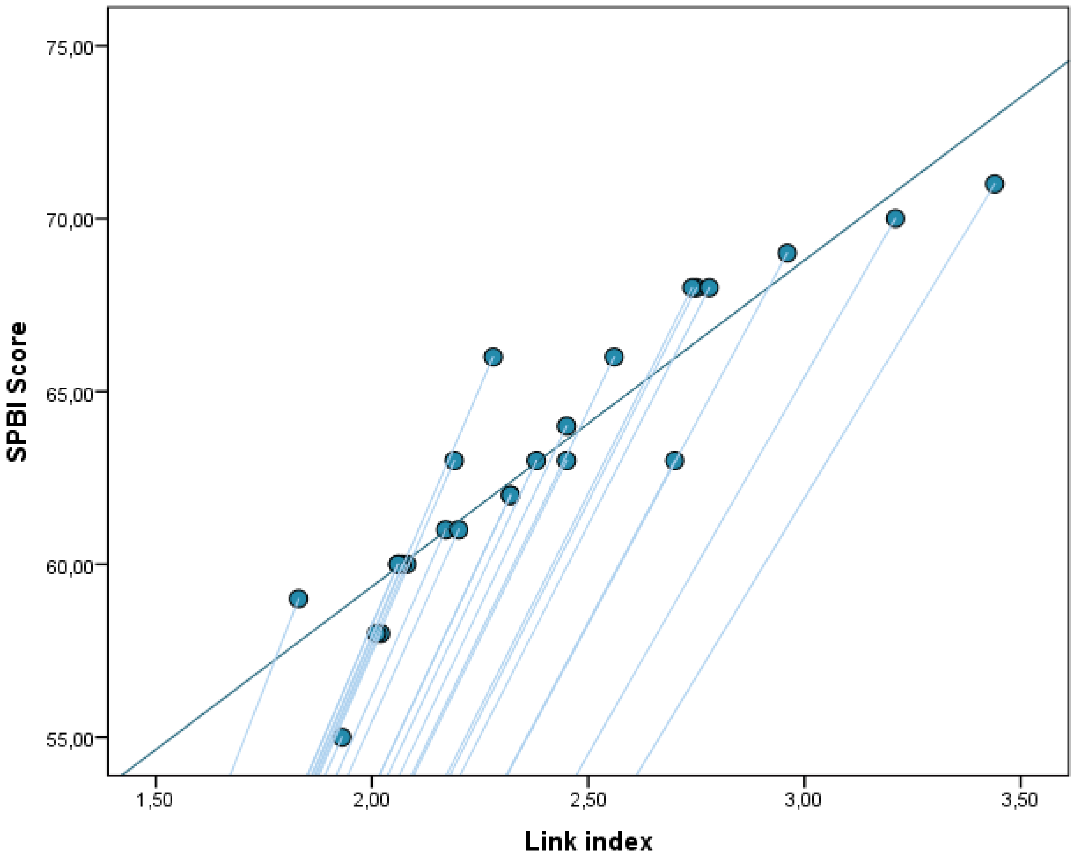

Figure 26. Correlations between Link indexes and SPBI scores

Figure 26 presents the correlation between participants' SPBI scores and link indexes. As shown in Figure 26, there is a positive correlation between link indexes and SPBI scores. The coefficient of correlation; r= .923, was measured at the .01 level. As the link index is the ratio of the total moves to the total links, generating connections between the ideas is more important than generating unrelated ideas. According to Goldschmidt (2014), link index is an indicator of linking productiveness. The results showed that people with high SPBI scores tend to have high link index values, which seems to indicate post-formal thinkers tend to create more interconnected ideas. As high SPBI scorers are better at perceiving actual or potential relations between previously unrelated matrices of thought, the high scorers might have more ideas to link each other, even if the previous unrelated ideas are contradictory. When Table 9 is inspected it can be seen that although P16 (SPBI score: 63) and P25 (SPBI score: 71) generated very close numbers of total moves, 136 and 135, P25's linking productiveness was denser than P16, which was resulted with obtaining a higher link index. Indeed, the difference in density between P16 and P25 can be easily seen at their linkographs:

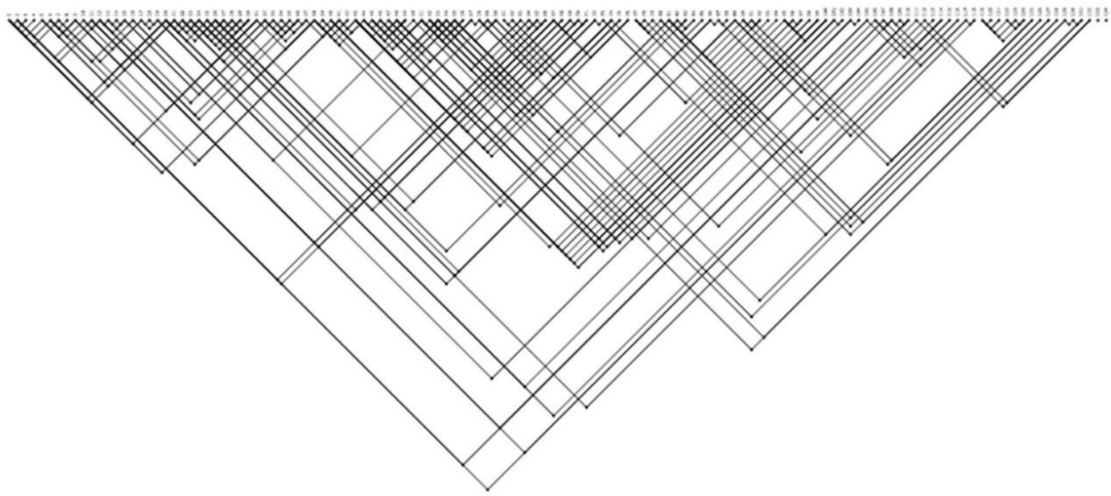

Figure 27**.** Linkograph of P16

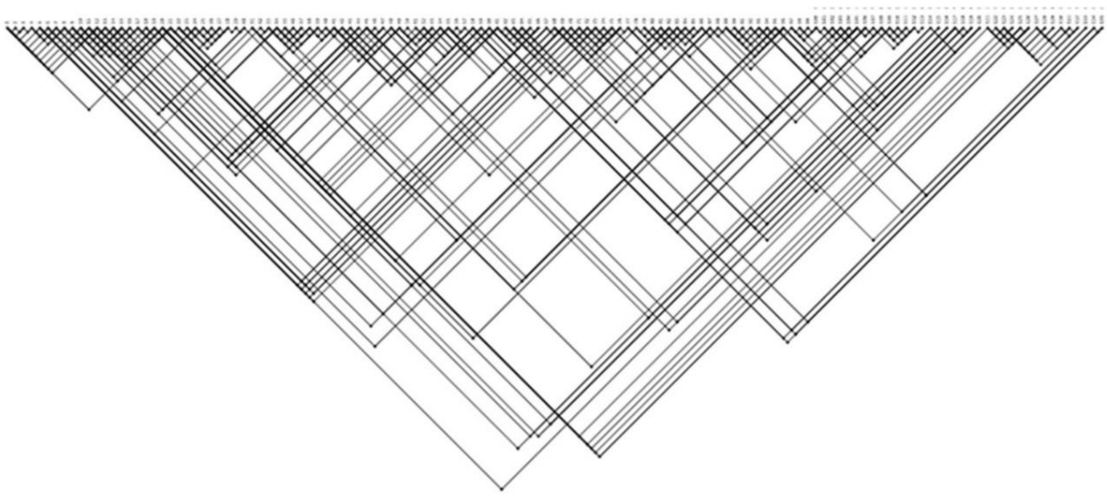

Figure 28. Linkograph of P25

As seen in Figure 27 and 28, P16 has a loose linkograph and P25's interlinks are denser. Also, P16 has several orphan and unidirectional moves which indicates poor design sessions. Thus, it can be inferred that P16 had a lack of synthesizing the sub-ideas into one. This lack also can be traced from the chunk production of the participants: whereas P25 has homogeneous chunk distribution during a whole design session, P16's chunk distribution uneven. Moreover, it can be seen P16's linkograph, after 85th move, backlinking activity dominates her design process, and moves have forelinks couldn't breed much. This structure indicates a retrospective analysis, as well as applying formal thinking:

M94: Of course its texture is important
M95: Especially its material
M96: Manufacturing by wood also emphases being natural
M97: Yet, humidity caused by sea would affect it [wood] badly
M98: Still, I think it [seating unit] should be a *warm* material
M99: Maybe we can give the perception of depth with the material
M100: or with the colour of material
M101: or, as I said before, should we pick a focal point to create the perception of depth?
(…)
M106: This canopy is coming from the back corner
M107: and attaching to the upper corner

M108: It [canopy] can be complex by this way

M109: But people shouldn't feel its complexity

M110: As we said at the beginning when people come here [seaside], they seek for peace, thus we shouldn't reflect its [canopy's] complexity to them

M111: Of course the direction of light should be taken into consideration

M112: Sun's direction

M113: I just realised that I started with a plane plan, but then my design become a wavy form… more common… whereas four corners rise [at the beginning], now it is like… I realised… the form… starting from this [pointing the sketch] back corner, and goes to cross corners

M114: Do I want to design a more complex form?

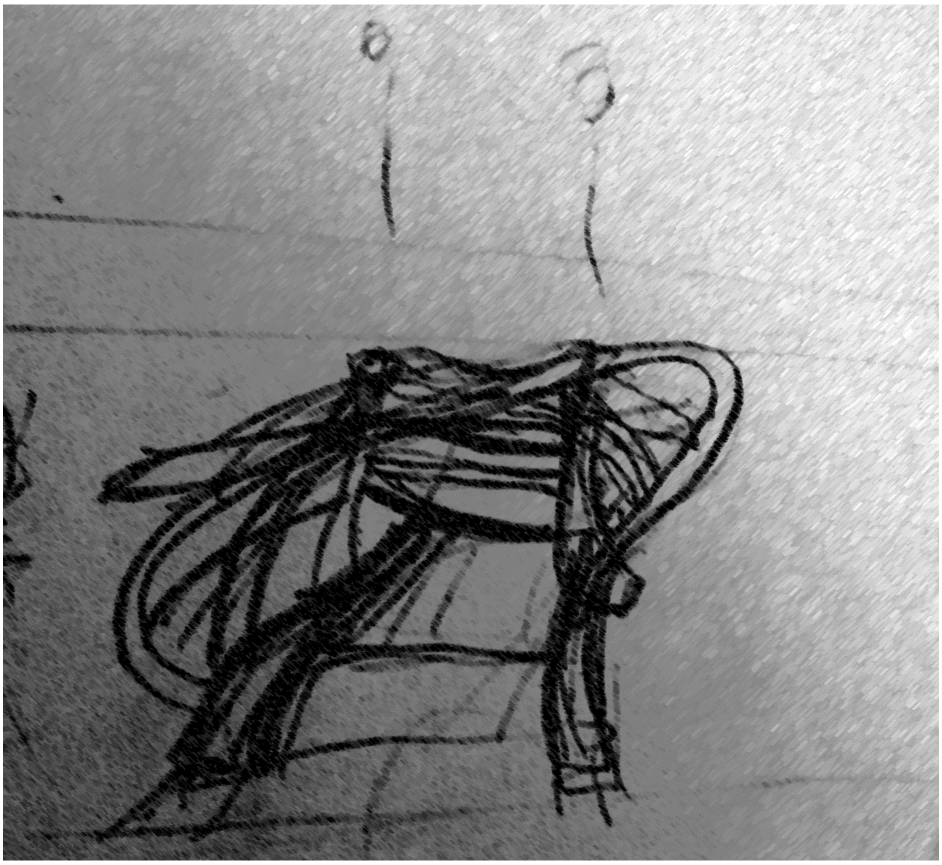

Figure 29**.** Sketch of P16

Move94 to Move98, P16 does not try to break open her first thoughts: if it is a seating unit it should be wooden; if the seating unit will be next to the sea, it should look as a part of nature; if the seating unit will be wooden and next to the sea, the humidity will cause corrosion. Indeed, the fixation on wood and adding a canopy for acquiring shade have been observed at most of the protocols of participants with a high number of absolute answers. Move106 to Move113, P16 conducts a retrospective analysis of her design which yields her to an introspective question at Move114. By doing so, P16 re-evaluate the appropriateness of the responses to her previous proposals, as well as examining the proposals' harmony with her intentions (see Figure 29 for the sketch).

To further investigate the relations, the participants' Link index scores were compared with the numbers of participants' absolute, relativistic and dialectical answers.

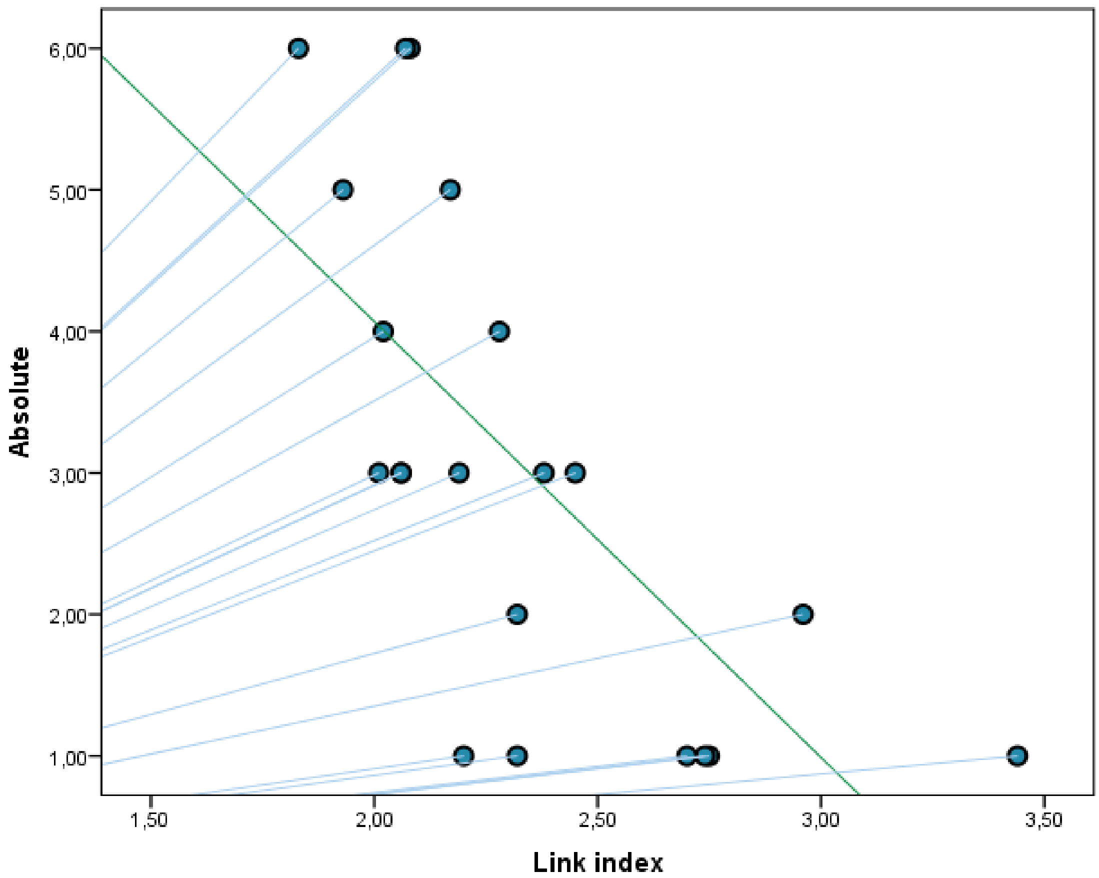

Figure 30. Correlations between Link indexes and number of Absolute statements chosen

One of the hypotheses of this research was that the formal thinking might have negative effects on idea generation productivity and also on creativity. The basic argument of the hypothesis was grounded on the fact that operating in closed systems allows generating a limited number of possible ideas and a limited number of links among them. To confirm the hypothesis on idea generation productivity link index scores correlated with a number of absolute statements chosen (Figure 30). As can be seen in Table 9, there is a statistically significant negative correlation; $r = -.681$ ($p < .01$), between absolute thinking and link index. So, the results do support the hypothesis. This was consistent with Wu and Chiou's (2008), Yang et al. (2010) and Blouin and McKelvie's (2012) findings.

In this research, it has proposed that formal thinking's dualistic conception nature, such as right vs. wrong, true vs. false, weak vs. strong, disallows synthesizing which cause lack of idea generation and interlinking productiveness. As mentioned before, although applying absolute thinking on solving the technical sub-problems might be useful to achieve appropriateness, it is strongly believed that applying it on the sub-problems that could only be solved by using tacit knowledge would harm to the novelty of the end-product. Two partial protocol analysis of P4 (6 Absolute answers at SPBI) and P21 (6 Absolute answers at SPBI) are given as an example below:

(P4) M45: Structure… Its material should be light.

(P4) M46: There is wood [as a material]

(P4) M47: but… It [wood] absorbs water, damp from sea and decomposes quickly

(P4) M48: The best and only option is steel

(P4) M49: then it has been decided: it will be steel!

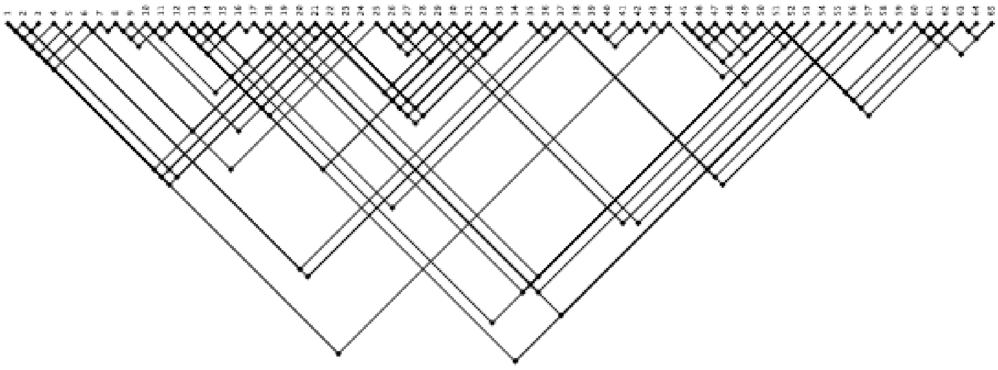

Figure 31. Linkograph of participant 4

(P21) M72: First of all… the material may be associated with nature, maybe wood

(P21) M73: Ok… manufacturing the portable units by wood is contradictive in the context of being kinetic, and especially it may damage to meadows

(…)

(P21) M78: Of course it might not be logical to fix the module on meadows, nor making it [the module] heavy

(P21) M79: Maybe I can place the static modules at the periphery of the meadows

(…)

(P21) M95: Maybe these ones [portable units] will be extremely light

(P21) M96: that one can position those [portable units] as one on the top of another or next to each other… by doing so, it [being kinetic] can trigger different usages that I cannot predict now

(P21) M97: That is why it [the units] should be simple

(P21) M98: should be light

(P21) M99: and should be natural. What could it [material] be then?

(P21) M100: I said simple, light, natural… Ah… Also, it [portable unit] shouldn't harm the meadows while moving it here to there. I should think about how I can reduce the potential damage it will cause. How can I decrease it [the damage]?

(P21) M101: Meadow is a soft surface… on the solid surface we can create a stress on the ground by using weight for fixation, so on the soft surface, we can distribute the stress on the contact area

(P21) M102: In my opinion then… I should design the portable units with large contact areas to preserve meadows

(P21) M103: and design the static ones as exact opposite

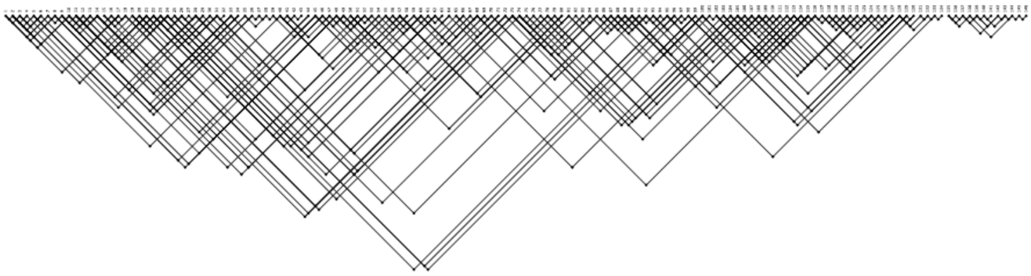

Figure 32. Linkograph of participant 21

When the partial protocols of P4 and P21 are examined it can be seen that both starts with the idea of using wood as a material and challenge this idea in the context of appropriateness. Both participants questions wood's physical qualities and decide that wood wouldn't be feasible. P4 jumps to the conclusion as soon as possible and decides to replace the wood with another one, steel. So, for him, the sub-problem is getting solved in five design moves, and he never questioned the material again. Formal thinkers tend to avoid contradictions (Kramer et al., 1992). Thus, it can be expected from formal thinkers that just picking a known answer from a closed system, which disallows them generating new ideas. P4's partial protocol is a very good example of formal thinking and how it might cause a lack of idea generation productiveness.

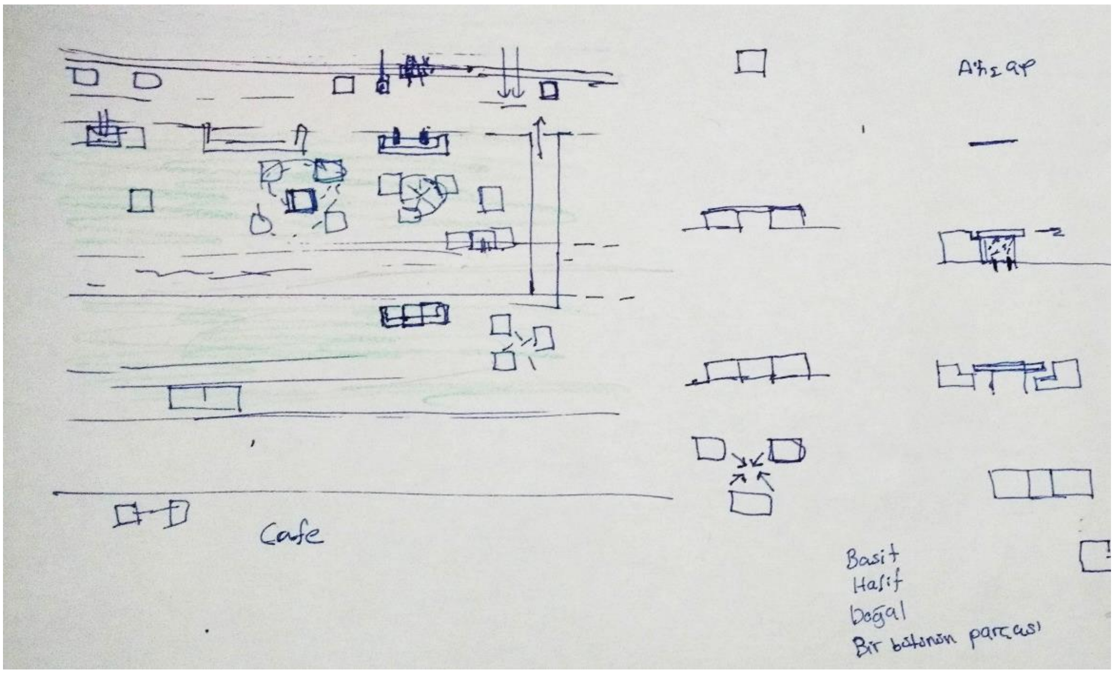

Figure 33. Sketch of P21

On the other hand, after voicing wood, P21 starts to explore contradictions of his ideas: e.g. being heavy but also being portable (see Figure 33 for the sketch). Then he points out the potential relations between the seating unit's portable parts and where they may be positioned, leads him to raise a new idea about static units. Yet, simultaneously, he considers to designing the portable units as simple and light in order to reduce the potential damage on meadows, yields him to think about the basic physics. By doing so, he generates new ideas about the form. By not picking a known answer and not concluding fast, P21 able to generate multiple ideas and interlinks by exploring possible contradictions and relations between unrelated sub-problems. Indeed, the output of their thinking styles and the quality of design processes can be seen at their linkographs (Figure 31 and Figure 32). Whereas P4 has loose webs which cannot create chunks, P21 has a very well connected web and chunks. Thus, it can be inferred from the linkographs that P4 mostly applied formal thinking during the Task2, whereas P21 applied post-formal thinking.

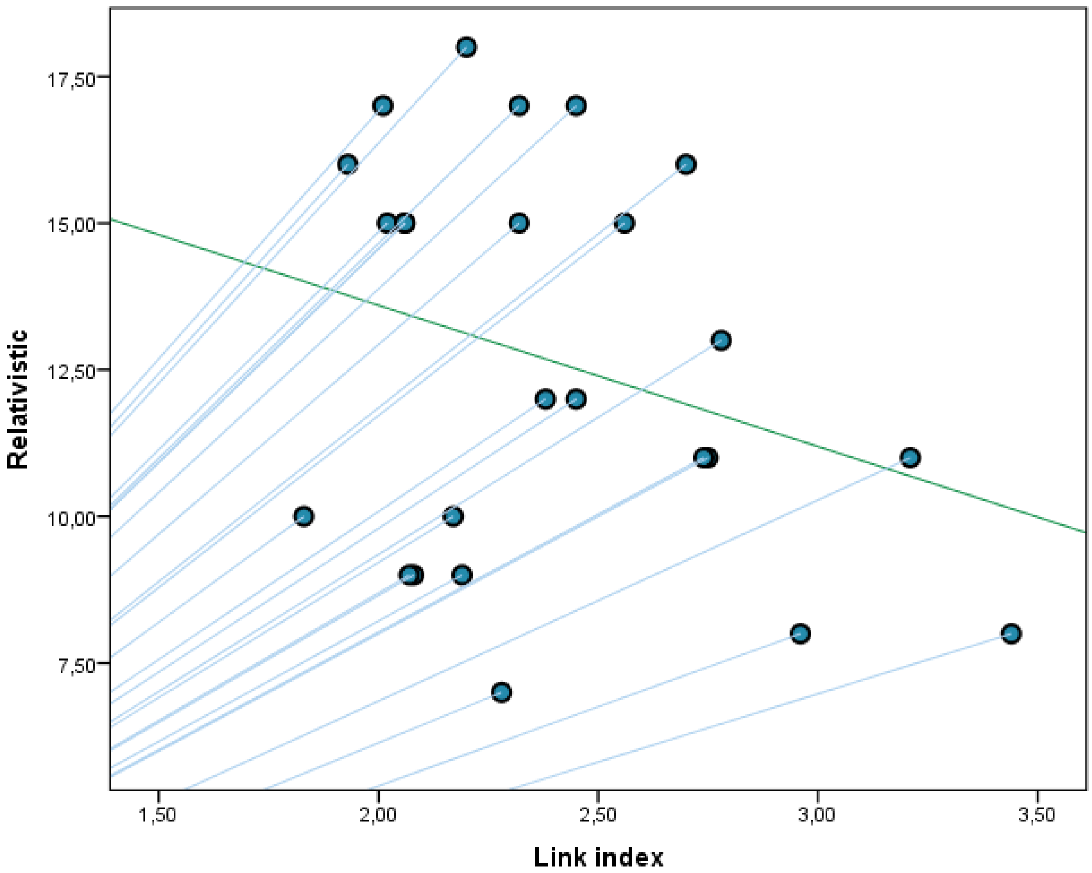

Figure 34. Correlations between Link indexes and number of chosen relativistic statements

In this research, it was expected that relativistic thinking is positively correlated with the idea generation productivity. However, results of the comparison between link indexes and relativistic thinking showed a weak negative relation; r= -,291 (See Figure 34), contradictory with Wu and Chiou's (2008) findings. The possible reasons for the negative correlation are discussed under another sub-chapter.

Relativistic thinking based on contextualist worldview (Kramer, 1983). That is to say, in relativistic thinking, there are no universal truths, but contextual truths. If the truth is broken away from its context, it will lose its meaning (Morris, 1988). Therefore, the ideas generated by relativistic reasoning are closely connected to subjectivism. Thus, relativistic thinkers are aware of the existence of personal variance and contextualism. An example of relativistic thinking in the design process of P11, who has one of the highest relativistic scores, is given below:

M53: if we talk about this… height… the situation of not being able to see while passing behind [the seating unit]… yet, in the meantime… Yes, the people passing behind won't be able to see you but I want that they can see what kind of a seating unit is there

M54: Maybe which is why… might see [the seating unit] while passing by be enough?

M55: Anyway there is such a thing… because one of them [seating unit components] is filled and the other one is empty… Ok, I won't render it [controlling the visibility] by height, but by fullness-emptiness

M56: By this way, I achieve controlling visibility

M57: Because I don't want the passengers to see the user, yes, they shouldn't see the private life here, it might be disturbing for the seater. But they [passengers] could see the sea from the gaps

M58: I don't know if the gaps will be big, but it will be this much tall

M59: Of course I am not pushing [the limits of design] to force them [passengers] to see the sea… They might not want to see the sea… but at least, I want to make them feel an empathy for the user. By doing so, they might be attracted to use it [seating unit]

M60: On the top of it why I am… When s/he [passenger] feel tired, s/he will come and sit on it anyway… at the end, it is its function. And, s/he will experience the difference anyway.

M61: For example… what are the differences? It [seating unit] allows seeing the sea. Maybe being ergonomic. Yes! It should be comfortable!

M62: Maybe s/he will say: "I don't want to lie down here, I just want to sit. Because I need to rest just for five minutes, then I will go." So, then what?

M63: Then it [seating unit] will be two parts.

M64: This part will be the seating unit, and this part will be where s/he will put her legs on. Now it [the design] makes more sense.

M65: What else…? The colours… I use these colours just because I like them. So, they [the colours] don't have any functions, like toning with the environment. Some users might not like them [the colours] though.

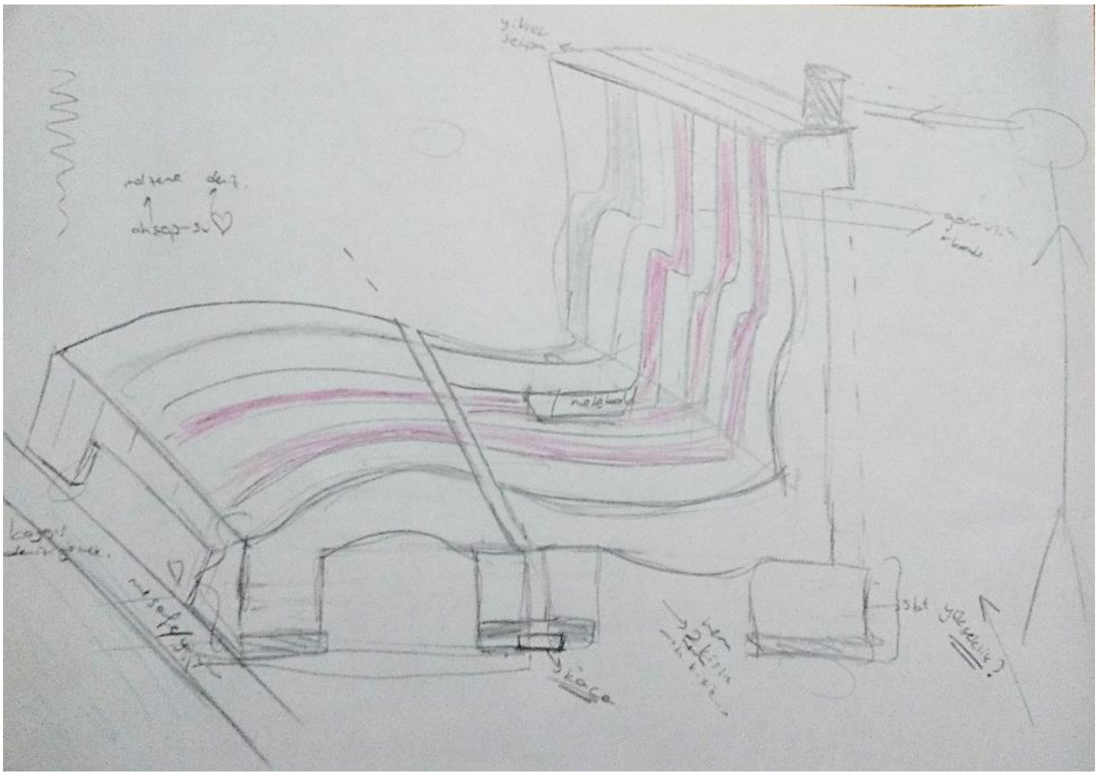

Figure 35**.** Sketch of P11

When the P11's partial protocol is analysed, it can be seen that her major concerns are focused on how people will use it, will perceive it, and about her personal intentions and wills. Indeed, almost all of her design session structured by such concerns. While designing the seating unit, her relativistic thinking can be traced to the moves how actual and potential users can interact, as well as their interaction with seating unit by creating imaginary scenarios. In other words, she conceptualized her design according to subjective preferences. Especially *M57*, *M59*, *M62* and *M65* are very good examples of relativistic thinking. At M57, she attempts to link her own intentions and users' potential preferences with passengers' potential act, seeing the sea. At *M59*, she questions herself and points out that she is aware of the existence of other subjective preferences and she respects them. Even, she voices her intentions on creating a medium allows the growth of empathy. At *M62,* she challenges herself again by an imaginary dialogue which ends up with a form decision, among the attempt on understanding other subjective circumstances. *M65,* on the other hand, is a purely subjective statement. As can be seen above, in her design session consideration of subjective differences directly effects the concept of the design, as well as her seating unit's form. Moreover, when her partial protocol compared with P4's and P7's partial protocols, which are given above, it can be said that relativistic thinking allows creating more interlinks than formal thinking.

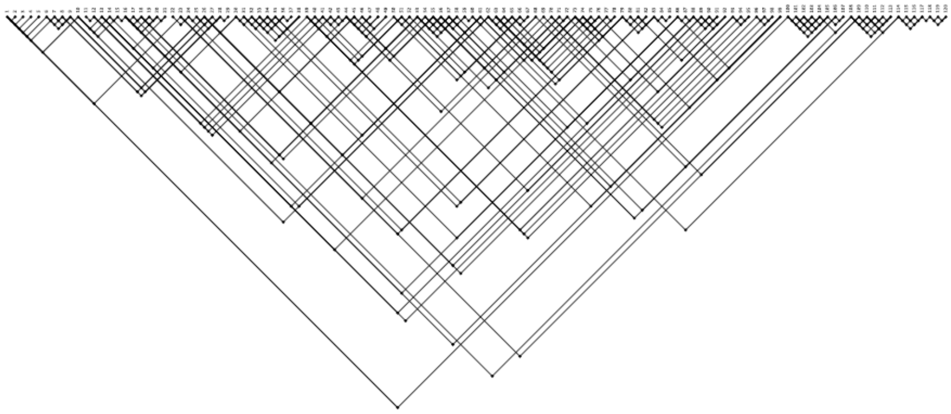

Figure 36. Linkograph of participant 11

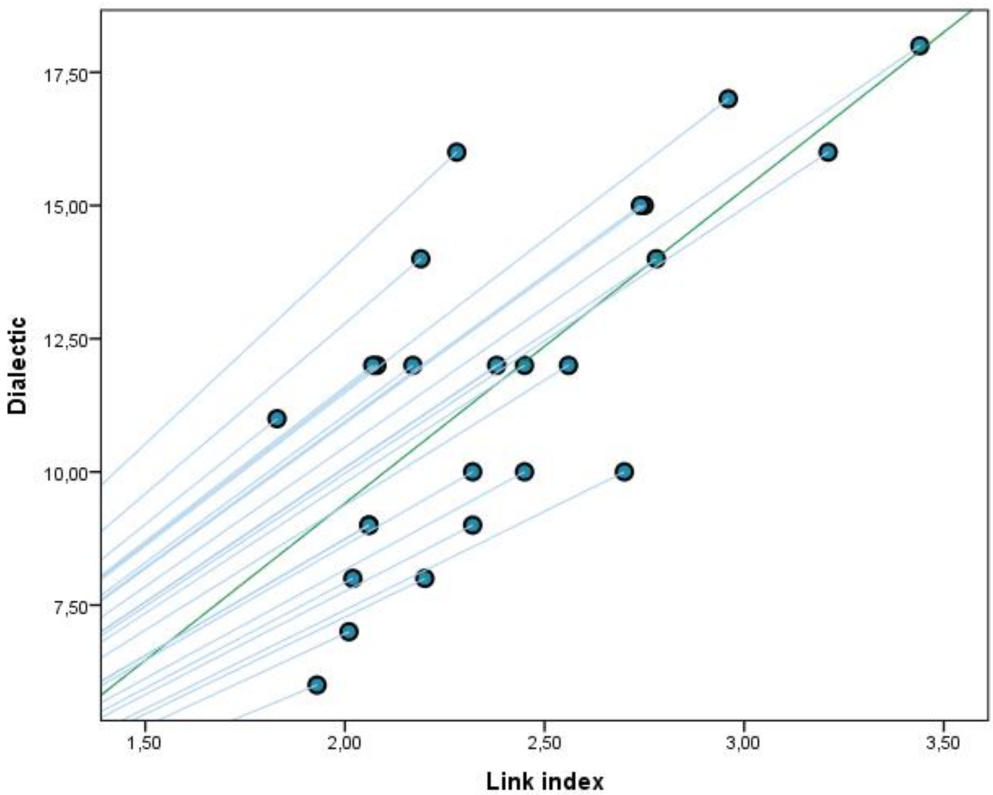

Figure 37. Correlations between Link indexes and the number of chosen dialectic statements

One of the main hypotheses of this research was that the dialectical thinkers might be more successful at idea generation productivity than relativistic and formal thinkers. Indeed, as expected, the correlations between link indexes and dialectical thinking showed a significant positive relation; r=,745 (See Figure 37). This result was also consistent with Wu and Chiou's (2008), Yang et al. (2010) and Blouin and McKelvie's (2012) findings.

As dialectical thinkers are aware of that there are multiple realities and truths (Kramer, 1989) they can also be able to link knowledge across multiple perspectives at once. Unlike to the relativistic and formal thinkers, dialectical thinkers are capable to conceptualize contradictions as interrelated and part of a whole. These abilities might also allow them to create more intense linking that increase idea generation productivity. Moreover, "dialectical thinkers see changes in thinking as natural, expectable, and valuable. Thus, a dialectical view of knowledge encourages individuals to willingly move away from past points of view and to perform the "set-breaking" (Wu and Chiou, 2008, p. 240). This characteristic of the dialectical thinkers might help them to have a successful evolution process, that in turn boosting the idea generation productivity. The partial protocol analysis of P23 is given as an example below:

M62: the things [seating units] can turn into open, semi-open or closed would provide much more advantages.

M63: Ok then! Instead of moving only at X and Y coordinates, maybe I can think about a movement at Z coordinate too. How can I [seating unit] perform at Z coordinate?

M64: First, I should design [movements at] X and Y coordinates coordinate. Hmm… Maybe I can start with the plan.

M65: I can imagine it as a necklace… A necklace that I would love to give as a present to my girlfriend… I don't have a girlfriend anyway, but still…

M66: Maybe it [seating unit] will look like an *S*

M67: Well… with its movement, it [seating unit] might be perceived as aesthetical

M68: What we told before: gatherer… It [seating unit] will be a gathering place for different groups, it will be kind of booster for to gather.

M69: Wow! Accidentally… Now it [seating unit] can serve for two different groups at the same time! If I can catch it… but catch what?

M70: Let me explain it: if you think the mechanical concept I mentioned before with the shafts, and integrate it here [pointing the sketch]

M71: By this way, you can rotate it from here [pointing the sketch], and the two groups sitting back to back before, can sit as a big group and can listen to the guitarist

M72: And when I semi - rotate it and position vertically… hmmm… it becomes a personal seating unit! Just for a person!

M73: By this way, you can rotate it from here [pointing the sketch], and the two groups sitting back to back before, can sit as a big group and can listen to the guitarist

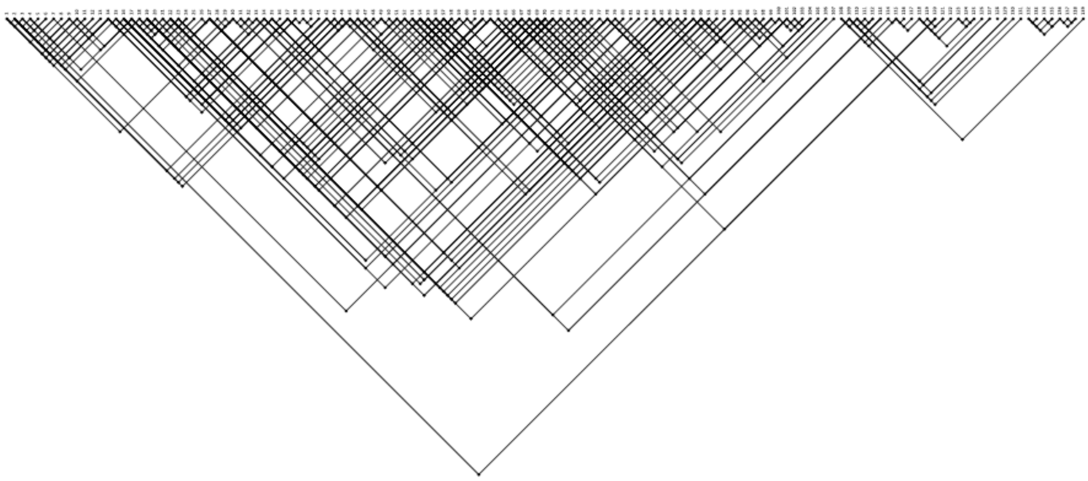

Figure 38. Linkograph of participant 23

As seen in the partial protocol analysis of P23, it can be seen he links multiple unrelated ideas at once. User groups appear as contradictory elements of the design session: single user versus groups, and groups versus groups. To conceptualize these contradictions as interrelated and part of a whole, he holistically approaches to the design. He combines the ideas of being able to move at X, Y, Z coordinates with user scenarios and with the *necklace* idea, which leads him to an *S* form. At P23's partial protocol analysis no idea is left behind and orphan, but getting re-framed in order to be linked to the others (see Figure 39 for the linkograph and Figure 40 for the sketch).

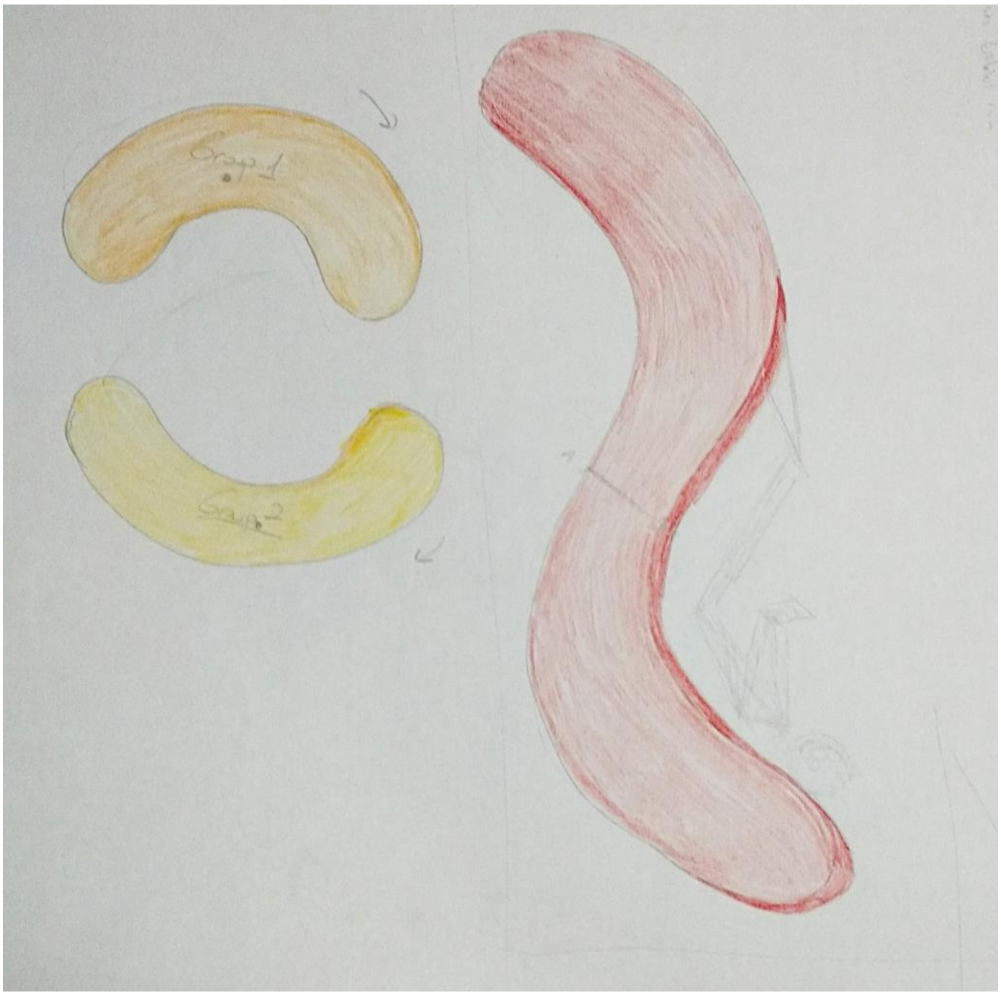

Figure 39. Sketch of P23

4.1.2. Relations between SPBI Scores and Critical Moves

Generating as many as ideas are crucial for the design process because *quantity breeds quality*. But, if the interlinking of the ideas is poor, generating many ideas would be useless to reach a creative and successful design proposal. Yet, the ideas called as critical moves (CMs) that foster the interlinking productivity is much more crucial for the design process. CMs are the golden boys of the moves. As mentioned in Chapter 3, CMs are accepted as the main indicator of creativity (Goldschmidth, 2014, van der Lugt, 2001). Tatsa (2005) and Goldschmidt and Tatsa (2005) have shown that the ideas heading to novel solutions tend to have plentiful interconnections. Starting from these point of views, in this research CMs are accepted as a variable of creativity, and the threshold for CMs determined as 6 and more.

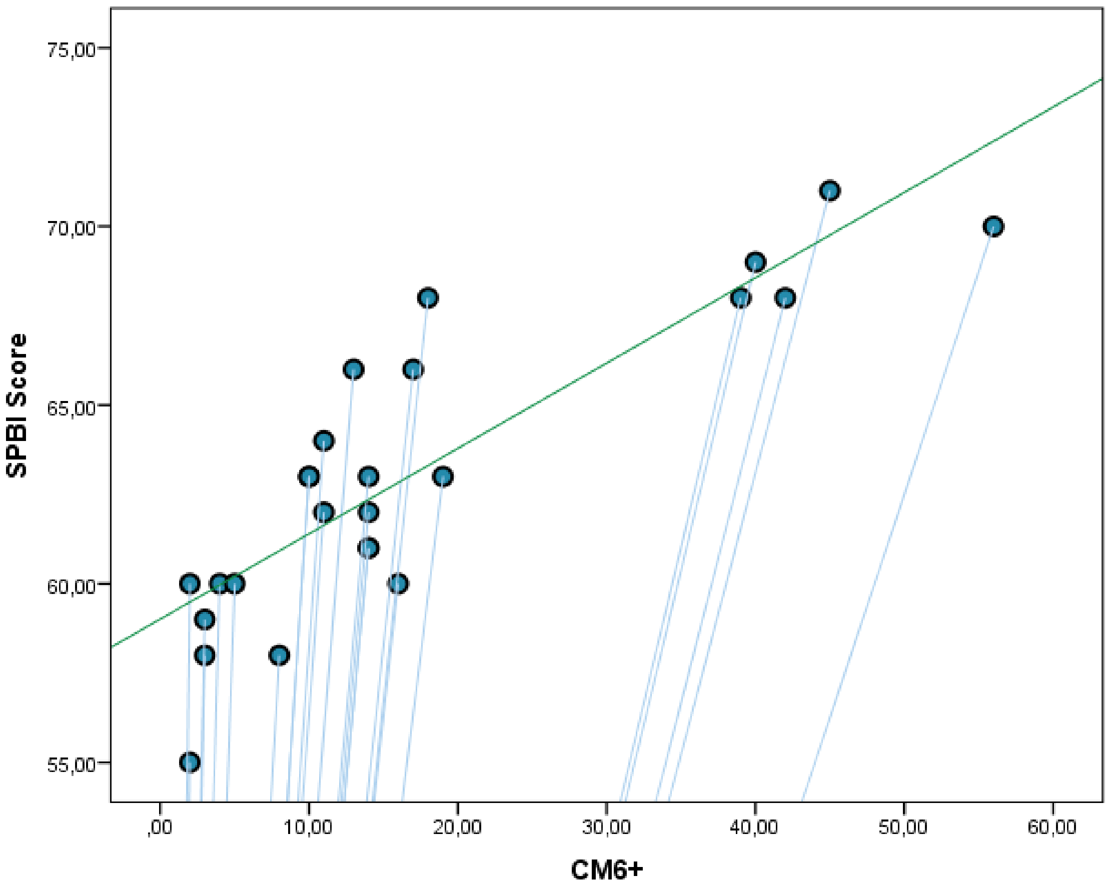

Figure 40. Correlations between SPBI Score and number of CM6+

One of the main hypotheses of this research was that the post-formal thinkers might be better at generating critical moves than formal thinkers. Indeed, when the SPBI scores were correlated with the critical moves which created at least six links (CM6+), given at Figure 40, it was found that these two variables strongly correlated to each other, r=,858. Even more, when Figure 40 is examined, it can be seen that three groups clearly distinct from each other. The first group consisting of P1, P2, P3, P4, P5, P6 and P8, who have more absolute answers at SPBI. The second group consisting of P7, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19 and P21, who have more relativistic answers. And the last group consisting of P20, P22, P23, P24 and P25, who have more dialectical answers.

The detailed list of generated CM6+s of participants is given in Table 10. As seen at the table, as the scores get higher in SPBI, the scores get higher in CMs.

Table10. Detailed numbers of CM6+

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25
CM6	1				1	3	6		5	8	5	2	5	4	6	6	5	6	7	13	8	15	11	22	19
CM7		1	1			1	2	2	3	5	2	3	5	5		6	1	5	1	11	6	12	8	13	14
CM8	1	1	2			1	4	1	3			3	1		2	3	1	1	2	4	2	6	4	9	1
CM9		1	2	1				1	3	1	3	2	1	1	1	3	3	1	1	1		5	2	3	8
CM10			1	2			1				1					1	1	2	1	1	1	1	4	3	1
CM11			1				1						2							2	1	2	3	2	
CM12			1				2								1				1			1	1	1	1
CM13												1						2		5			2	1	1
CM14																							1		
CM15																							1		
CM16																							1	1	
CM17																									
CM18																				1			1		
CM19					1																				
CM20																								1	
CM21																									
CM22																							1		
CM42																				1					
Total	2	3	8	3	2	5	16	4	14	14	11	11	14	10	10	19	11	17	13	39	18	42	40	56	45
SPBI Scores	55	58	58	59	60	60	60	60	61	61	62	62	63	63	63	63	64	66	66	68	68	68	69	70	71

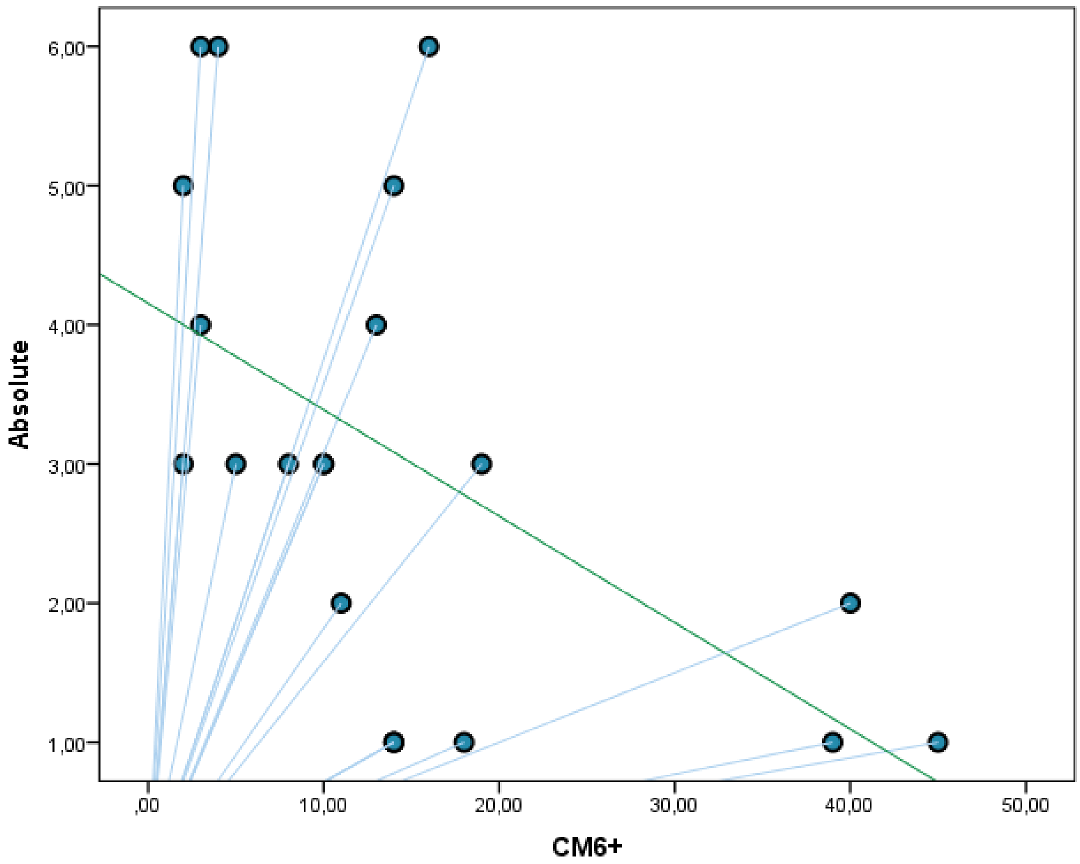

Figure 41. Correlations between CM6+ and the number of chosen absolute statements

Similar to the SPBI and link index correlation, results of the comparison between CM6+ and absolute thinking showed a significant negative relation; r= -,536 (See Figure 41). In the line with the hypothesis, the results proved that the absolute thinking might have a retrogressive effect on creativity. As mentioned before, formal thinkers operate in closed systems and their thoughts' nature is dualistic. Thus, even though a sub-problem can be solved with a relativistic or dialectical approach and the novel and appropriate solution belongs to an open-system, formal thinkers tend to stick to a well-known solution space to them, called also as *met-before (*Tall, 2008). Tall (2008) defines *met-before* as "to be a current mental facility based on specific prior experiences of the individual" (p. 6). When the participants' protocols are analysed, it was seen that every single participant started with a *met-before* as a source domain and starting point (see Table 11).

Table 11. *Met-before*s in protocols

Source Domain				
Activity	Seating	Lying	Reclining	
Environment	Sea	Sun	Meadows	Wind
User	Group	Groups	Single	
Material	Wood	Metal	Plastic	

When the protocols were analysed for the evolutions of *met-before*s, it was seen that formal thinkers tend to avoid cross-examining their ideas and tend to superficially re-frame their *met-before*s. Therefore, that is inferred that the main reason of lacking on CM generation might be rooted to lack on re-framing and combining ability. P2's partial protocol is given below as an example:

M1: First I think what I am going to design a seating unit for the seaside. I mean it [seating unit] will be at seaside… Then the question is how can I experience the sea?

M2: I mean, just seeing the sea is not enough at all.

M3: I might want to experience the sea by touching… I think I can start with this idea

M4: I mean, at a seaside… a plain seaside… my seating unit may reflect the motion of sea… the smooth motions of the sea.

M5: Ok… this reflection might be given by curves. But how?

M6: These curves may penetrate the sea at a point and can create a connection

M7: With more sharp lines…

M8: sharply coming from sea and become curvier on the land which reflects sea's smooth representation

M9: By this way, people can experience the sea by touching at this part [of seating unit]… where it [seating unit] penetrates the sea. These are the only ideas pop up in my mind so far.

M10: Maybe here, at the part, it penetrates the sea, people can experience the sea also by visual and audial sense. I mean the people who don't want to experience it by tactual sense. I can think such a start to my design. But I have no idea what can I think else…

M11: I think it [seating unit] should dominate the whole seaside

M12: It [the form] is coming like this [pointing the sketch], people can go into the sea from this point… continuous with curves… through to beach… then it becomes sharp again. That's all… I don't know what I can design more…

M13: Oh! It [seating unit] can be helpful to gather people

M14: Circular…

M15: By doing so, I can make it [seating unit] suitable for groups too, not only for single users. I mean, now I am not experiencing the sea alone, but as a community.

P2's design session is predicated on dualities; seeing vs touching, inside vs outside, curve vs straight line, single vs group. These dualities arise from her *met-before*s: sea, wave, and potential user(s). She superficially re-frames her concept on the close knowledge domains connected to her *met-befores*, and she avoids searching for deep connection from a distant schema. Whenever she feels she is blocked, instead of challenging herself and searching for connections from un-related knowledge domains, she prefers jumping on another well-known *met-before*, which ends up with superficial re-framing and blockage. When her linkograph is inspected (Figure 42), it can be seen that she has clear small chunks that loosely connected to each other. It also shows that her design session was not very well connected and fertile in the context of CM generation.

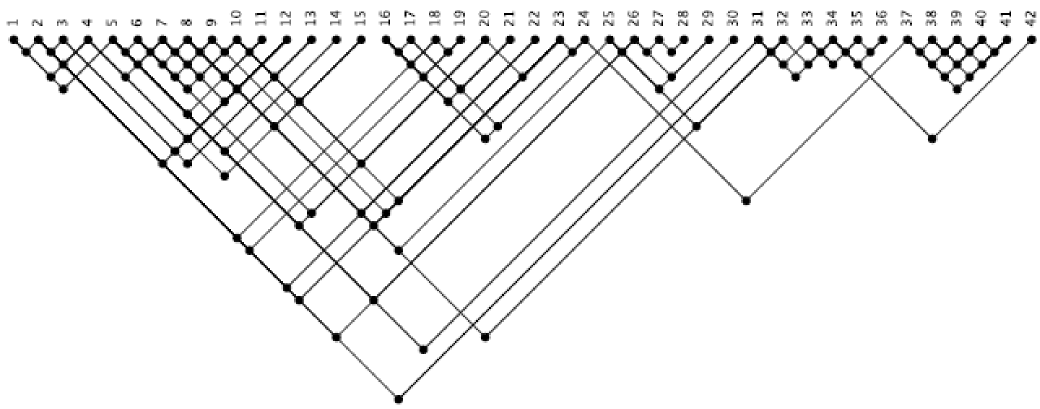

Figure 42**.** Linkograph of participant 2

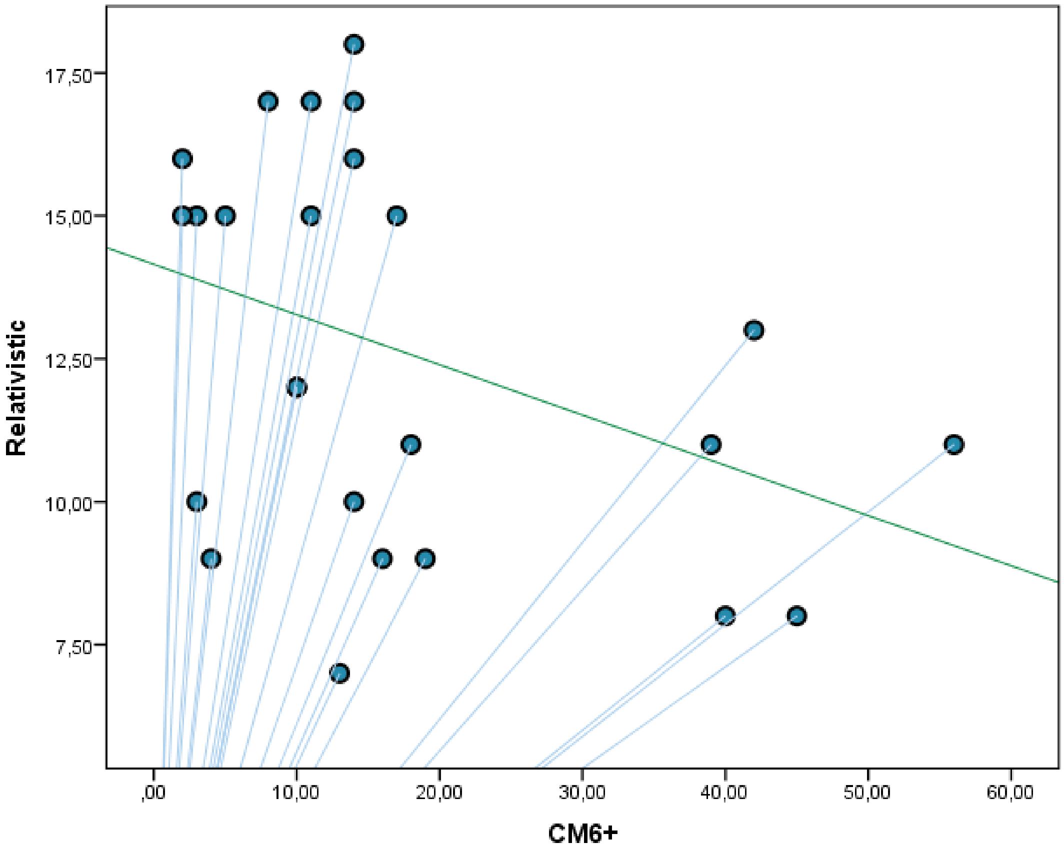

Figure 43. Correlations between CM6+ and the number of chosen relativistic statements

In this research, it was expected that relativistic thinking is positively correlated with the idea generation productivity. However, When the CM6+ scores were correlated with the number of chosen relativistic statements, given in Figure 43, it was found that these two variables weakly correlated to each other, r= -,391. The possible reasons for the negative correlation are discussed under another sub-chapter.

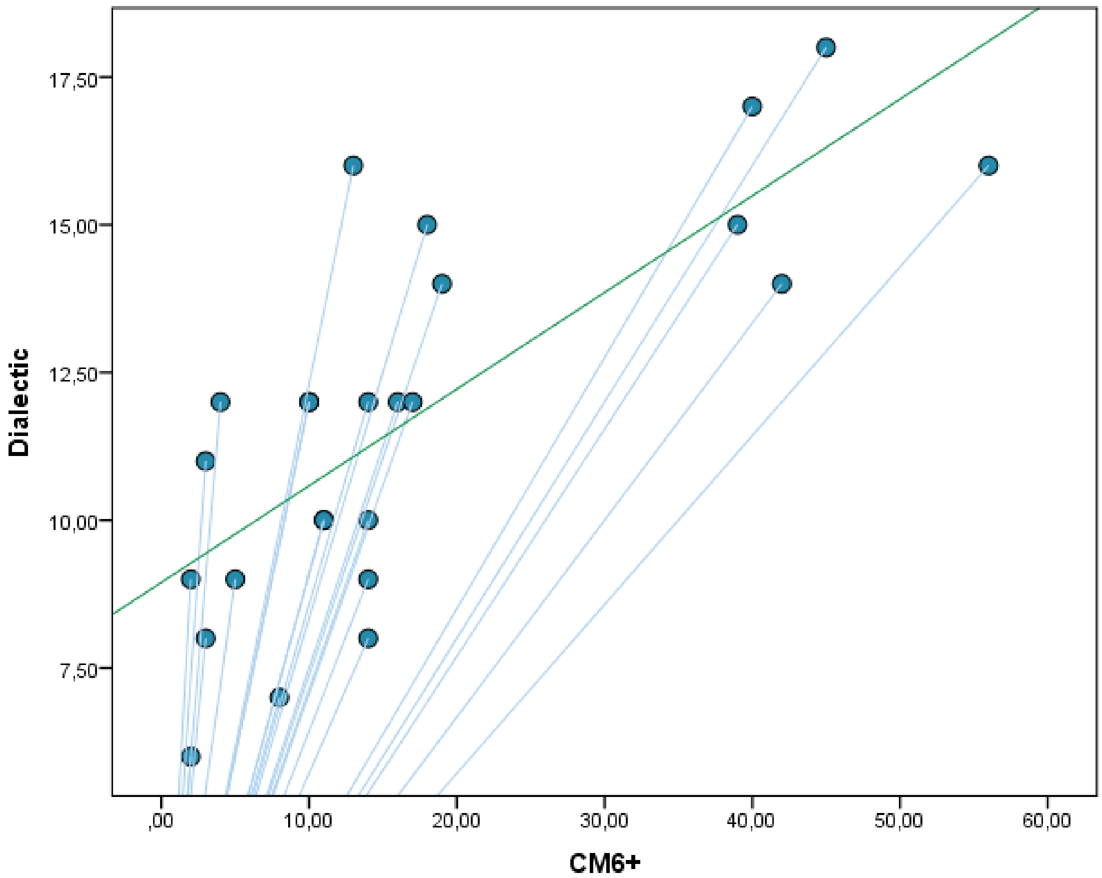

Figure 44. Correlations between CM6+ and the number of chosen dialectical statements

Figure 44 presents the correlation between CM6+ scores and dialectical thinking. As expected, there is a positive correlation between the scores. The coefficient of correlation; r= .760, was measured at the .01 level.

As dialectical thinkers work in open-systems and tend to search novel relations between distant and even contradictory knowledge chunks, they might be more successful at generating CMs. When the protocols were analysed for the evolutions of *met-before*s, it was seen that the post-formal thinkers tend to profoundly re-frame and combine the *met-before*s in order to reach an *Aha!* moment, that also generates a CM. As an example, P22's (with 15 dialectical answers in SPBI) partial protocol is given below:

> *M27*: What kind of things come from the sea? Standard background research… breeze, smell… or the five senses… let's start with our senses!

(Till M90 he classifies the things which are related to the sea, environmental characteristics and the five senses, as well as deciding which are important for his design among them, e.g. smell of diesel fuel, day and night view of the sky and the sounds of seagulls.)

M118: Ah… I forgot the sounds of waves, I should add this to the list also. Footnote: Danger! Danger! On very windy days the waves themselves become a danger!

M119: I should add something here to prevent getting wet…Ah! Getting wet is related to tactual sense! I don't know if it [wetness as a tactual sense] will be beneficial for the design, but let's keep that in the mind in case.

M120: Let's skip the auditory sense for now. Nothing has come out of taste sense anyway too…

M121: Tactual sense… it related to the material also… hard surface, smooth, semi-rough, soft surface, rough, jagged, sea, sticky, wet…Shall I let seated people get wet? Nah… It would be too much!

M122: Ok! Let's back to the base. Interactions… Visual interaction with sea traffic… skip it!

M123: Visual interaction with nature… street animals, birds… Yes! I can add a small birdbath!

M124: Eh… It [seating unit] still useless for cyclists. I am going to add some features for usage of cyclists too.

M125: The most important is shadow! I should find a solution for it too!

(…)

M149: Visual interaction with nature… at that part of Kordon, there is less green… I know what I am going to do: I will add pots to the seating unit which contains small trees! By doing so I will provide shadow! A home for the birds!

(…)

M211: Birdbath… it will be here [pointing the sketch], there is free space for it [birdbath]

(…)

M214: I need a tap here for the birdbath.

M215: Great! Cyclists can also use this tap to wash their hands and faces after they lock their bikes! And by this way, while they use the tap, birdbath can be refilled!

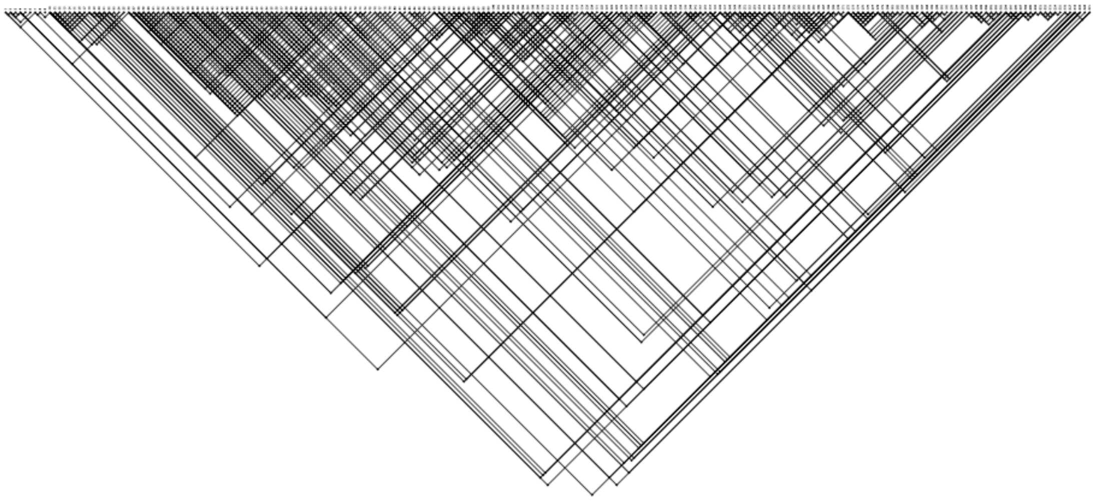

Figure 45. Linkograph of P20

Similar to the P2, P20 also use the *met-before*s: sea, wave, and potential user(s), but in a different way. To re-frame his *met-befores*, P20 searches connections from distant knowledge domains by setting a context, the five senses, which allows him to keep a holistic approach. His decision of using the five senses as a base of the design process at *M27* becomes a CM which breeds 42 new ideas (see Figure 45). He re-frames his idea (*M27*) by connecting it to his *met-before*s from distant knowledge domains several times, e.g. at *M121* he tries to relate tactual sense with material which yields him to question himself on wetting the users. At *M122*, by searching connections with visual sense, he decides to add a birdbath, which is an uncommon feature for a seating unit. Again, at *M149*, he connects visual interaction with the need of protection from sun and birds. Later on, he connects his birdbath idea with the needs of cyclists. As seen, he very well integrates his ideas by finding novel and deep connections. On the contrary to formal thinkers, as a post-formal thinker, he develops his ideas by working on sub-problems in tandem in a set context. This approach also helps him in overcoming blockage. When his linkograph is inspected, it can be seen that he has big chunks that firmly connected to each other. It also shows that his design session was fertile in the context of CM generation.

4.1.3. Possible Reasons for the Negative Correlations between Relativistic Thinking and Creativity

There is no direct research on links between relativistic thinking and creativity. Wu and Chiou (2008) and Blouin and McKelvie (2012) concluded that the relativistic thinking has boosting effects on creativity by interpreting of a z-score obtained by combining the relativistic and dialectical scores into a single measure. Thus, in this research, it was expected that relativistic thinking will be positively correlated with the idea generation productivity and creativity. Yet, the results showed weak correlations. Thus, the results of this study are in contradiction with Wu and Chiou's (2008) and Blouin and McKelvie's (2012) conclusions. At their latter creativity research Yang, Wan and Chiou (2010) decided to exclude relativistic thinking as a variable "because postformal operations theorists have proposed that relativistic thinking represents a subset of postformal operational thinking (e.g., Kramer and Woodruff, 1986; Basseches, 1989; Kramer, et al., 1992)" (p.6). Yet, also the mentioned researchers (Kramer and Woodruff, 1986; Basseches, 1989; Kramer, et al., 1992) accepts relativistic thinking as a different thinking style than dialectical thinking.

In this research, it is proposed that there might be three possible reasons for the negative correlation of relativistic thinking with idea generation productivity and creativity. First of them is that the ipsative nature of SPBI, which means getting a high score on one thinking style results with getting low scores on the others. In other words, although the relativistic thinking is one of the postformal thought processes, it is also a competitor of dialectical thinking. Maybe that is why Wu and Chiou (2008) and Blouin and McKelvie (2012) felt that they need to combine relativistic and dialectical into a single score. Thus, to get a clear-cut conclusion on the reliability of using separate SPBI scores as variables, one should compare the effects of relativistic and dialectical thinking on creativity, independently from formal thinking.

The second proposal on possible reasons for the negative correlations is that relativistic thinking might have a regressive effect on creativity by inhibiting dialectical thinking. Dialectical thinking is considered the most advanced form of postformal thought (Laske, 2009) and for the researchers (e.g., Basseches, 1989; Blouin and McKelvie, 2012; Wu and Chiou, 2008) dialectical thinking has a greater emphasis on creativity than relativistic thinking. Yet, it is also known that during a problem-solving process post-formal thinkers might employ both thinking styles at different frequencies. Therefore, applying relativistic thinking more frequent than dialectical thinking might cause a regression on idea generation productivity and creativity, which might be reflected in the results as a negative correlation.

Third and the last proposal is that relativistic thinking might have a defocusing effect on the problem-solving process that weakens solution-oriented approach in the design process. As the relativistic thinking based on contextualist worldview (Kramer, 1983), solutions generated in a context would be useless for another context. Moreover, although the relativistic thinkers aware of that there are multiple perspectives, they can operate in only one context at a time. Therefore, during problem-solving process, with or without reaching a solution for the previous context they were operating in, they might skip to searching another solution for another context. Thus, they might lack on combining the generated solutions for different contexts and so apply a holistic approach, and end up with an unstructured thought process.

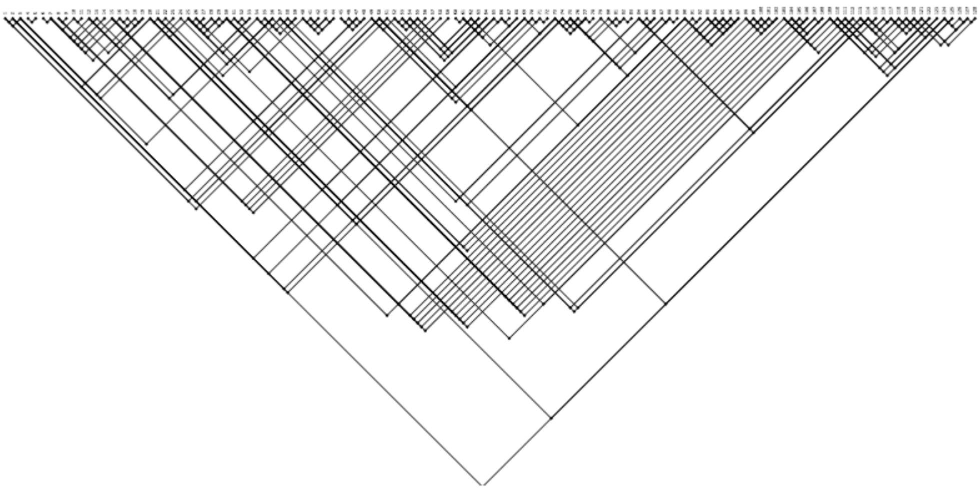

Figure 46. Linkograph of participant 9

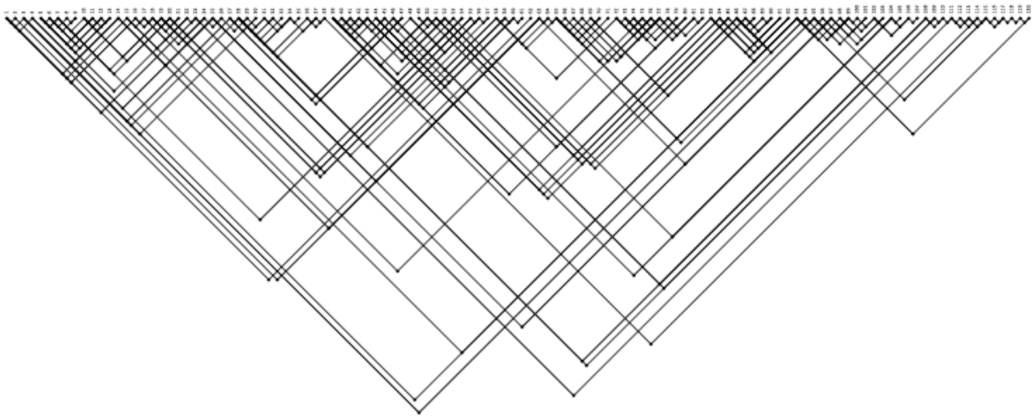

Figure 47. Linkograph of participant 19

As an example, P9's, with the highest number of chosen relativistic statements and P19's, with the lowest number of chosen relativistic statements linkographs are given above; as seen in Figure 46 and 47, P9 has a dispersed and poorly structured thought process, whereas P19's linkograph is aggregated and better structured.

4.1.4. Relations between SPBI Scores and Move Types

According to Teresa Amabile (1996) and Robert Sternberg and Todd Lubart (1999) generated ideas should be both novel and applicable to be accepted as creative. During the design process, designers search also for novel and applicable ideas to ensure the originality of the final artefact. To do so, designers apply an iterative process in which ideation and validation follow each other. Here, ideation ensures novelty, and validation ensures applicability. As post-formal think fosters idea generation productivity and the source of holistic thinking ability, post-formal thinkers might be better at ideation and validation process than formal thinkers. To assess this hypothesis, SPBI scores correlated with backlink and forelink scores, based on the Goldschmidt's (2014) conclusion that at a linkograph, forelinks are the graphical representations of ideation, where backlinks are the graphical representations of validations.

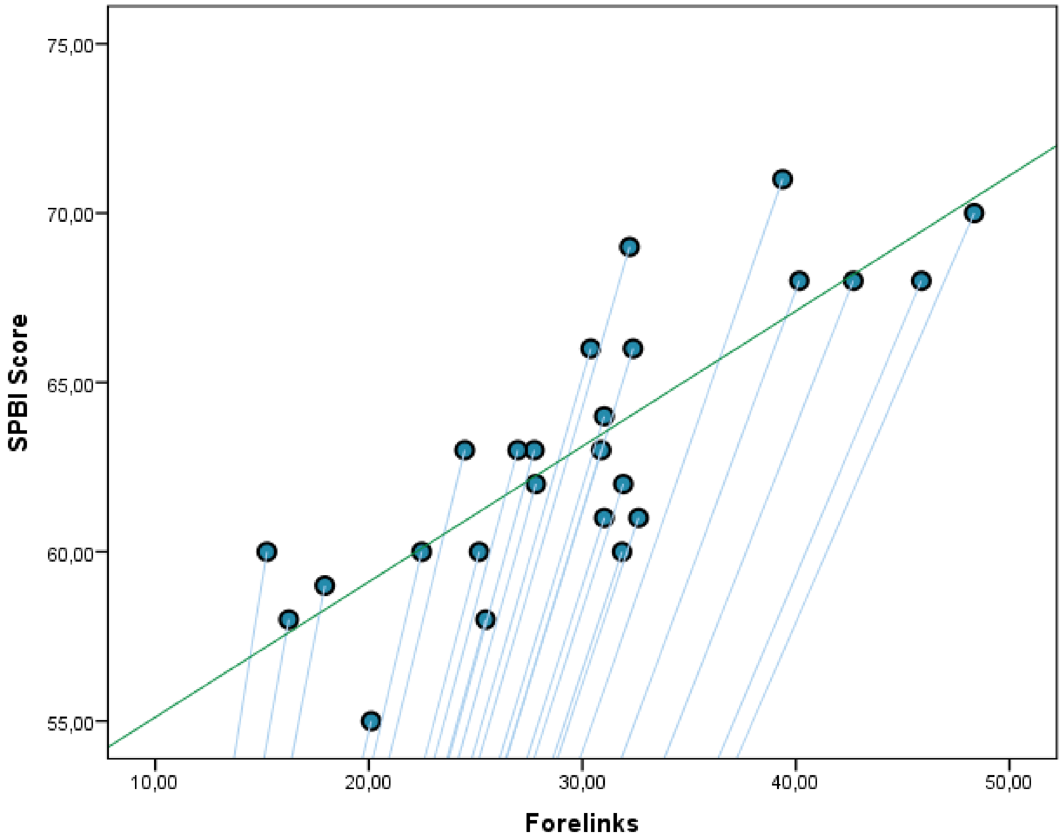

Figure 48. Correlations between SPBI scores and the number of Forelinks

When the SPBI scores were correlated with the number of generated forelinks, given in Figure 48, it was found that these two variables strongly correlated to each other, r= .822.

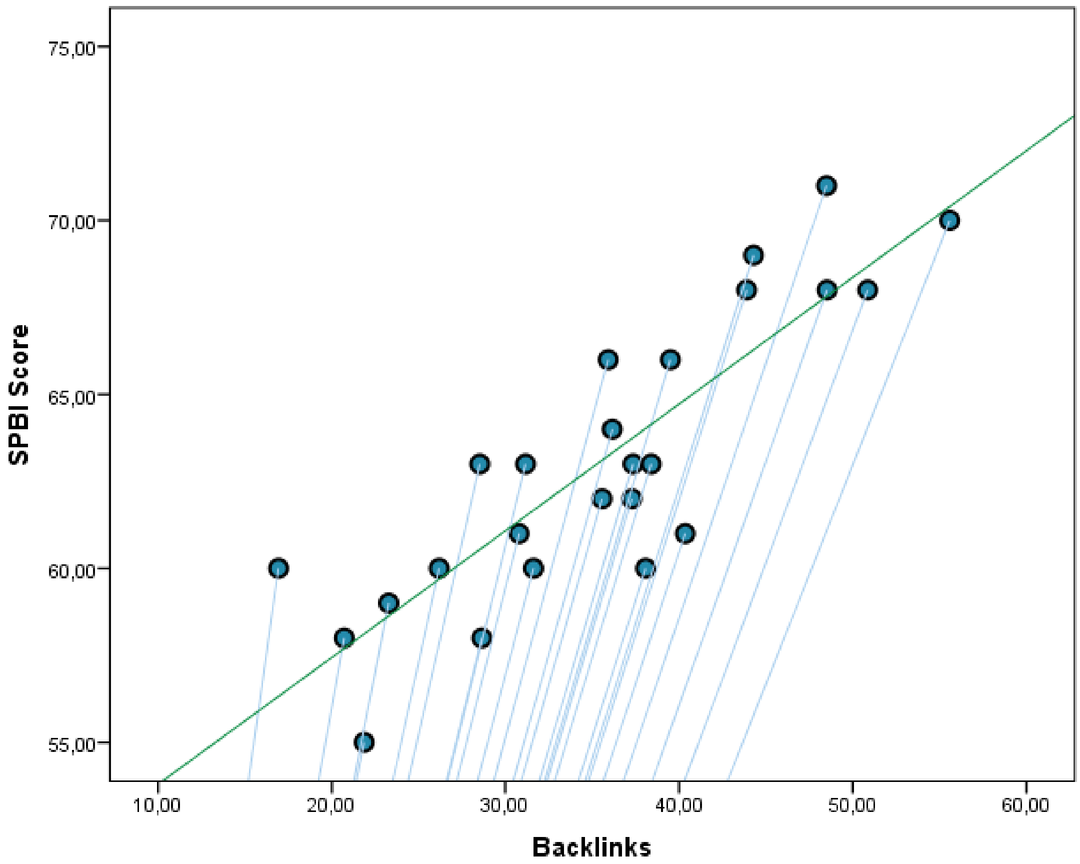

Figure 49. Correlations between SPBI scores and the number of Backlinks

As can be seen in Figure 49, there is a statistically significant positive correlation; r= .858, between participants' SPBI scores and the number of backlinks they generated during the design session.

The positive correlations of forelinks and backlinks with SPBI scores are in the line with the hypothesis that post-formal thinkers might be better at ideation and validation.

Table 12. Correlation matrix of Thinking Styles and Link Types

	Absolute	**Relativistic**	**Dialectic**
Forelinks	-,632	-,251**	,658
Backlinks	-,607**	-,356	,742**

Moreover, as seen at Table 12, results showed that dialectical thinkers are better at generating forelinks and backlinks than formal and relativistic thinkers, which also means that they are better at ideation and validation during at a design process.

4.2. Quantitative Analysis of Protocols: Post-formal Thinking and Syntactic Analysis

In order to examine the emergence of creative insights during the design process, and how postformal thinking types affect the production of critical ideas, a syntactic analysis is done. As mentioned before in detail, critical moves are associated with the creative insights, and are accepted as reliable indicators of creativity while assessing the quality of idea generation process (please see sections 2.2.4. and 3.2.1.4). Thus, to ensure the reliability of the chosen network that is syntactically analysed, critical moves and their total link counts are designated as a selection rule. To do so, every single participants' critical move thresholds are calculated and for getting a rich data to analyse, the CM networks which are rich in links are chosen (please see Table 13).

Table 13. Details of individual CMs and their links

Participant	Critical Move Threshold	Design Move	Count of Backlinks	Count of Forelinks	Total Links
P1	5	M9	3	5	8
P2	5	M10	3	5	8
P3	4	M26	4	3	7
P4	4	M19	4	1	5
P5	4	M9	4	1	5
P6	4	M47	4	6	10
P7	4	M97	5	2	7
P8	4	M44	4	7	11
P9	5	M90	4	5	9
P10	5	M21	5	7	12
P11	5	M57	4	6	10
P12	5	M59	4	5	9
P13	5	M26	5	8	13
P14	5	M61	6	5	11
P15	6	M26	3	6	9

(cont. on next page)

Table 13**. (cont.)**

P16	4	M51	4	8	12
P17	5	M10	5	3	8
P18	5	M46	5	7	12
P19	6	M76	6	3	9
P20	6	M149	6	5	11
P21	6	M24	6	5	11
P22	6	M76	5	6	11
P23	6	M63	6	10	16
P24	6	M143	11	6	17
P25	7	M20	7	13	20

After establishing the networks, the moves of CMs are coded according to two complementary coding schemes, FBS ontology and design contents to determine the design process activity and idea transformation type, as well as their syntactic content in the context of postformal thinking. For design contents coding, Yong Se Kim and his colleagues' (2005) information categories (IC) coding scheme (Table 14) is borrowed as it is the only one.

Table 14. Information categories (Source: Kim et al., 2005, p.74)

Main Categories	Subclass	Examples
Form	Overall Shape (OS) -Main object, Size, Color	With many curved shapes
	Component Shape (CS) -Unit	Speaker, LCD, fountain, lighting
Function	General Features (GF) -Common function, usage	Able to hold water, drain naturally, gives sense of stability
	Technical Feature (TF) -Explicit function, Operation	Bore a hole, attach a foothold
Context	External Knowledge (EK) -User social context	Kindergarten, seven-years-old, paddle their feet in water
Human (User)	Physical Elements (PE) -Body elements, Human moving, Gestures	Dip their feet, sit
	Mental Elements (ME) -Feeling, Responses	Boring, bears no burden
Designer	Intent (IN) -Domain knowledge -Designer's predictions or judgements -Process management	What children want, it appears to be a big fountain, lighting is needed too First of all, basic analysis about target user is needed.

First participant's CM threshold is determined as five, and the one with most links is *Move9* with 5 forelinks. Her CM and its backlinks are given below:

M9: that is to say, I think I should design a unit represents both water [sea] and soil [land]

BLs

M6: here in Kordon... there is something relaxing people when they sit next to the sea

M7: I mean, people want to experience the sea without caring where they sit

M8: or they want a place where they can feel the comfort of grass

Table 15 presents coded version of the moves:

Table 15. P1's coded network

	M9	**M6**	**M7**	**M8**
FBS	S	Bs^{i}	Be^{i}	$Be^{i'}$
IC	Form	Context and Designer	Human (user) and Designer	Human (User) and Designer

When the coded network is examined it can be seen that P1's design process activities are evaluation (Bs ←→ Be) and synthesis (Be' → S). She starts with determining the features of the targeted environment (*M6*) and comparing it with what these features do (*M7*). Then, she expands her concept by adding the feature of *comfort.* Except for the function (F), her network consists decisions about structure (S) and behaviours (B). When it comes to the content analysis, it can be seen that except function, she refers to Form, Human (user), Context and Designer. Although she connects only three ideas, she synthesizes (Be' → S) a critical idea which breeds five forelinks that affect almost half of her design process followed by a web (Figure 50).

When the network is analysed, it can be seen that she employs both relativistic and dialectical thinking. The relativistic thinking causes a conceptual expansion when she considers what users might want to experience (*M7* and *M8*) and transfers these qualities to her design by connecting sea and land by using dialectical thinking (*M9*). By connecting of two contradictory notions as the signifiers, she reaches a conceptual shift and a synthesis at her design process, and her CM becomes a creative insight.

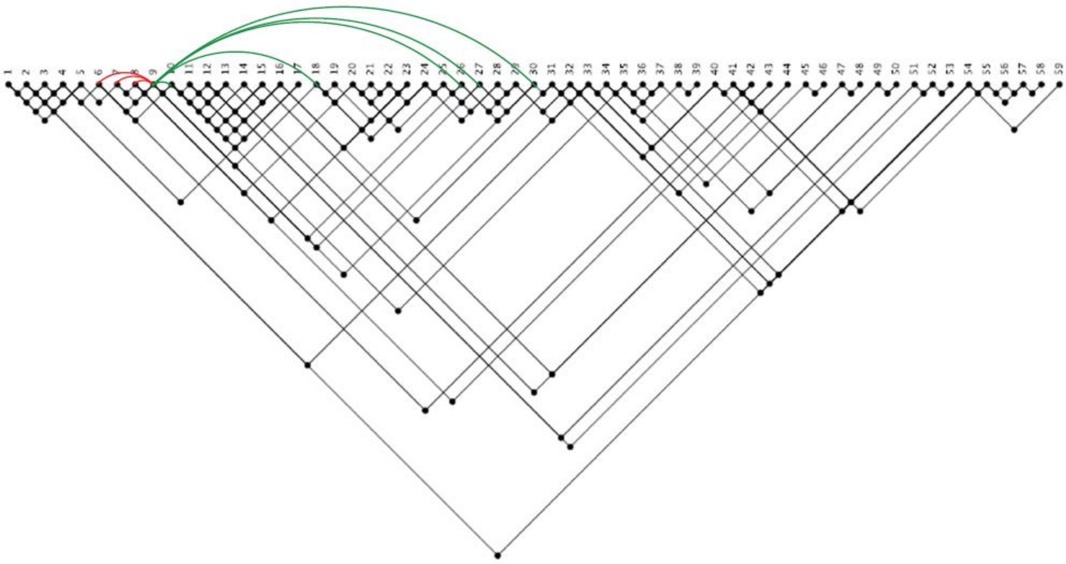

Figure 50. P1’s Linkograph

Second participant’s CM threshold is determined as five, and the one with most links is *Move10* with 5 forelinks. Her CM and its backlinks are given below:

> *M10*: Maybe here, where it penetrates the sea, people can experience the sea also by visual and audial sense. I mean the people who don’t want to experience it by tactual sense. I can think such a start to my design. But I have no idea what can I think else…
>
> BLs
>
> *M6*: These curves may penetrate the sea at a point and can create a connection
> *M7*: With more sharp lines…
> *M9*: By this way, people can experience the sea by touching at this part [of seating unit]… where it [seating unit] penetrates the sea. These are the only ideas pop up in my mind so far.
>
> Table 16 presents coded version of the moves:

Table 16. P2’s coded network

	M10	**M6**	**M7**	**M9**
FBS	Be’’	Be	S	Be’
IC	Form, Human (User) and Designer	Context, Form	Form	Form and Human (User)

P2’s process activity is determined as synthesis (Be → S), and it occurs when she transforms the idea of *penetration of curves and creating a connection* with *sharp lines.* At her synthesis dialectical thinking’s traces can be seen as she attempts to combine two contradictory notions, curves vs sharp lines. As *M6* is a conceptual shift itself, she expands her concept later on by adding user experiences to her concept and finally develops a creative insight which breeds five forelinks (Figure 51). Like as in P1’s protocol, conceptual expansion occurs when the participant employs relativistic thinking.

The content analyses showed that she addresses all information categories except function, and her network consist decisions about structure (S) and expected behaviours (B).

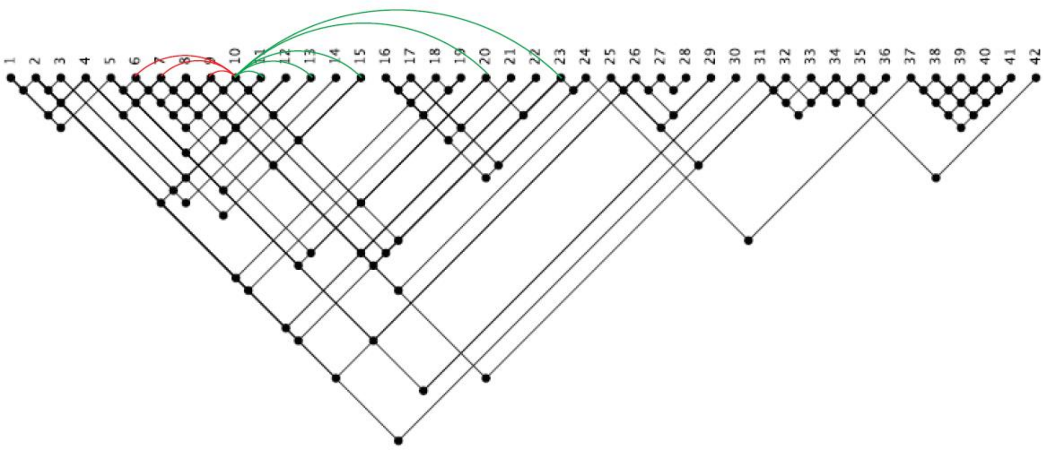

Figure 51. P2’s Linkograph

Third participant’s CM threshold is determined as four, and the one with most links is *Move26* with 3 forelinks. His CM and its backlinks are given below:

M26: will it [seating unit] be a combination of different materials?

BL:

M10: what will it [seating unit] be made of?
M23: for example wood, or the seating surface will be different?
M24: the seating surface can be [made of] a different kind of foam
M25: or something else, a different material

Table 17 presents coded version of the moves:

Table 17. P3's coded network

	M26	**M10**	**M23**	**M24**	**M24**
FBS	S'''	S	S'	S''	S'''
IC	Form	Form	Form	Form	Form

As seen from the coding, third participant's network is dominated by formal thinking and reformulation of ideas on structure (S → S'), thus there is no synthesis and conceptual shift in his design process. Yet, at the 26th move, he comes up with the idea of *combining materials.* At dialectical thinking, instead of choosing one notion/knowledge chunk and expanding it, combining two notions/knowledge chunks to get a fertile idea/solution is a feature, thus *M26* can be accepted as a weak dialectical thinking attempt. Although M26 breeds three FLs thanks to this dialectical thinking attempt (Figure 52), yet it cannot be accepted as a creative insight because of its lack of impact on the overall design process.

When his network examined, it can also be seen that his network does not address any information categories except form and any decisions except structure.

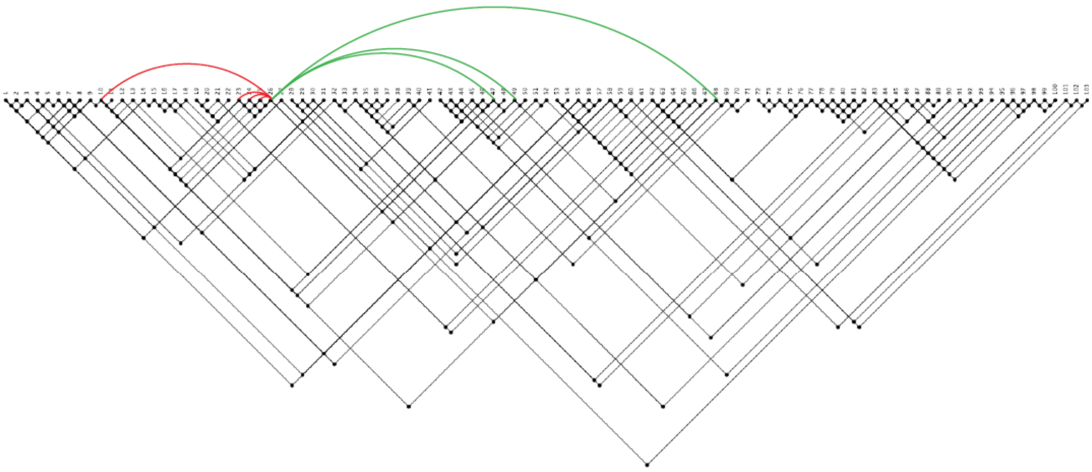

Figure 52. P3’s Linkograph

Forth participant’s CM threshold is determined as four, and the one with most links is *Move19* with one forelink. His CM and its backlinks are given below:

M19: a square can be created front of the seating unit

BLs

M10: [Kordon] starts with a square-like composition…

M12: thus this project [design of seating unit] can be like… combination of the three squares

M14: I can combine two squares with Kordon by designing a seating unit…

M17: Sea, Kordon, square… by this way, we can use the potential of the sea and design a unit hanging on the sea

Table 18 presents coded version of the moves:

Table 18. P4’s coded network

	M19	**M10**	**M12**	**M14**	**M17**
FBS	S’’’	S^i	S	S’	S’’
IC	Form	Context	Form	Form	Form and Context

P4's network starts with a contextual definition of the chosen district for the design (*M10*). Starting with his next move (*M12*), he reflects the features of the district upon his design without altering them, thus no synthesis occurs. At *M14* and *M17*, he expands his concept by reformulating the structures (S → S'). At *M17*, he introduces a new idea, a *unit hanging on the sea.* But he goes back the *square* idea without developing or combining this idea with previous ones. It can be seen on his network no significant transformation occurs, as well as no relativistic or dialectical thinking being employed.

When his network is inspected, it can be seen that his partial design process is also poor at addressing information categories. He only mentions about context and form, and structure. It has been believed that forelink and new idea production is fairly poor because of these missing elements of the design process, as well as the lack of postformal thinking (Figure 53).

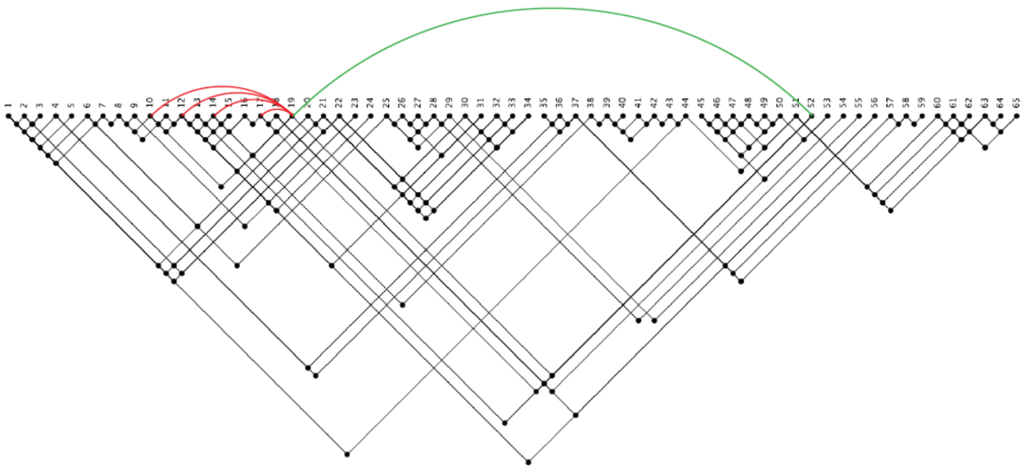

Figure 53. P4's Linkograph

Fifth participant's CM threshold is determined as four, and the one with most links is *Move9* with one forelink. His CM and its backlinks are given below:

M9: thus, the seating unit should combine these functions

BLs

M2: it [seating unit] should also be functional

M6: because user may do other activities while seating

M7: s/he may drink… s/he may eat

M8: because s/he may [want to] spend a long time [there]

Table19 presents the coded version of the moves:

Table19. P5's coded network

	M9	M2	M6	M7	M8
FBS	F	F	F^i	F^i	F^i
IC	Function	Function and Designer	Human (user)	Human (user)	Human (user)

P5's coded network starts with a judgement on how the design *should* be, and he defines the requirement as *function*. As *being functional* is too generic, he tries to expand his concept by introducing human (user) category to his concept. Yet, this introduction remains at a very basic level as he does not go further examination of possible activities of a user might perform while using the seating unit, nor variety or contradictions of user preferences. Thus, it cannot be said that he uses relativistic or dialectical thinking. Because of not altering the ideas, the process remains just as a poor conceptual expansion, and as he cannot reach to a conceptual shift no creative insight occurs.

When his network is inspected, it can be seen that his partial design process is poor at addressing information categories and carrying out design process activities. He does not consider context and form, as well as structure (S) and behaviours (B). It has been believed that forelink and new idea production are not successful and his design process is not creative because of the lack of postformal thinking and poorness of contents (Figure 54).

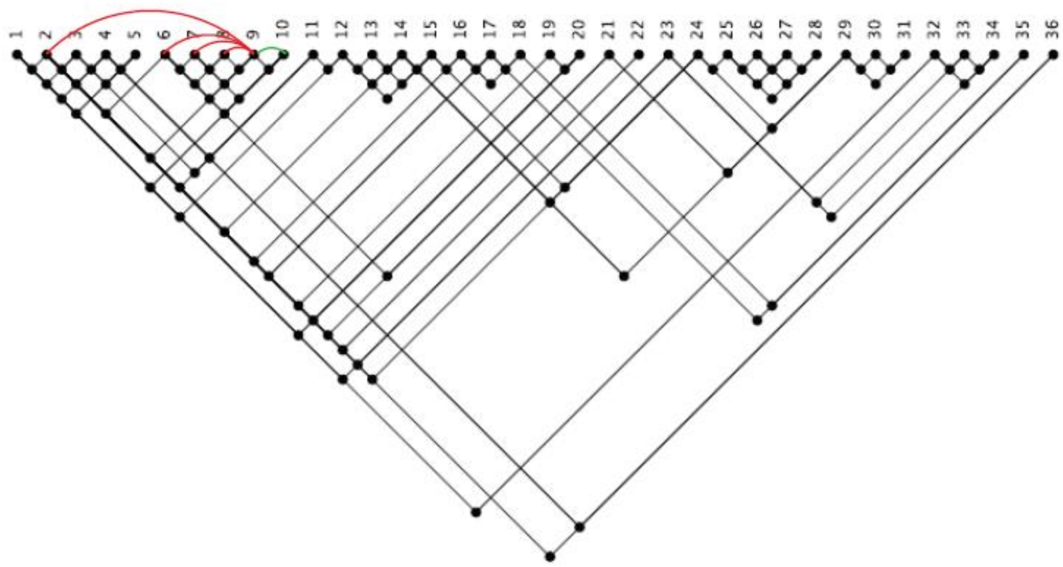

Figure 54. P5's Linkograph

Sixth participant's CM threshold is determined as four, and the one with most links is *Move47* with six forelinks. Her CM and its backlinks are given below:

M47: actually… I think it [seating unit] can be on the ground [low] than being in the air [high]…. Yes! I should think [design] something on the ground

BLs

M8: then… small things [seating units] on the ground that they [users] can sit on
M9: cushion like… let's draw a person here, who is fishing…
M45: for example… what kind of [seating unit] would I want to sit on?
M46: for example… definitely not a bank-like, but [I would want to sit on] a different thing [seating unit]

Table 20 presents coded version of the moves:

Table 20. P6’s coded network

	M47	M8	M9	M45	M46
FBS	S’’	S	S’	Be^{i}	S^{i}
IC	Form and Designer	Form	Form and Human (user)	Designer	Form and Designer

When P6’s coded network is examined it can be seen that P6’s design process activities are reformulation (S→S’) and synthesis (Be’→S). Her partial network starts with a design decision about form and at next design move she mentions *cushion* and expands her concept in the context of the form (*M8* and *M9*). Yet, she skips developing this idea until *M47*. At *M45*, she searches for an idea that *can make people want to sit on her design* by questioning her preferences, and again, she expands her idea by mentioning *not a bank-like*. At her CM, she goes back to ideas she states at *M8* and *M9,* and she abstracts *bank* as high and *cushion* as low. By this way, she introduces a contradiction to her concept and reaches to a conceptual shift which creates six FLs later on with the following web (Figure 55). When *M46* and *M47* are analysed, it can be seen that she uses dialectical thinking to reframe her concept in order to reach a conceptual shift.

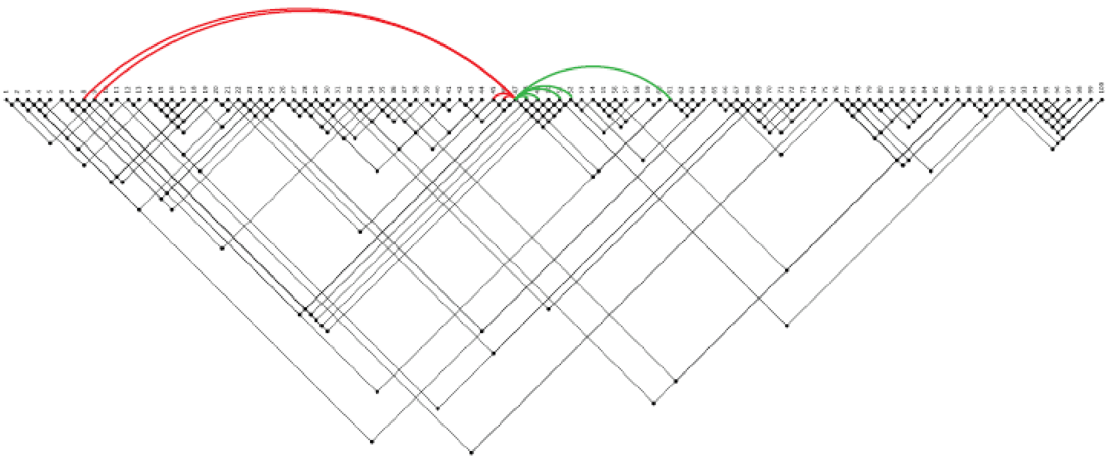

Figure 55. P6’s Linkograph

Seventh participant's CM threshold is determined as five, and the one with most links is *Move97* with two forelinks. His CM and its backlinks are given below:

M97: second and third [users] sit face to face instead of next to each other

BLs

M89: or... should I design it separately [discretely] for every single user?
M93: now… the first two [seating units] face to each other
M94: they [the two seating modules] be close to each other on the front
M95: if we attach them to each other, it [seating unit] becomes circular again
M96: thus, I am detaching them [the two seating modules]

Table 21 presents coded version of the moves:

Table 21. P7's coded network

	M97	**M89**	**M93**	**M94**	**M95**	**M96**
FBS	Bs'	S	S'	S''	Bs	S'''
IC	Human (user)	Form and Human (user)	Form	Form	Form	Form

P7's CM network starts with the decision of designing a partite seating unit. Then, he reformulates the decision (S → S'), and at following moves he starts to search for a sub-unit composition. By this way, he expands his concept. Later on, he analyses the consequences of his proposition at *M94* (S → Bs) and reformulates his idea once more.
It can be seen on his network no conceptual shift occurs, as well as no relativistic or dialectical thinking being employed.

When his network is inspected, it can be seen that his partial design process is also poor at addressing information categories. He only mentions about Form and Human (user). It can be also seen at his linkograph (Figure 56), his partial idea generation process does not have a significant effect on his overall design process, and thus M97 cannot be accepted as a creative insight.

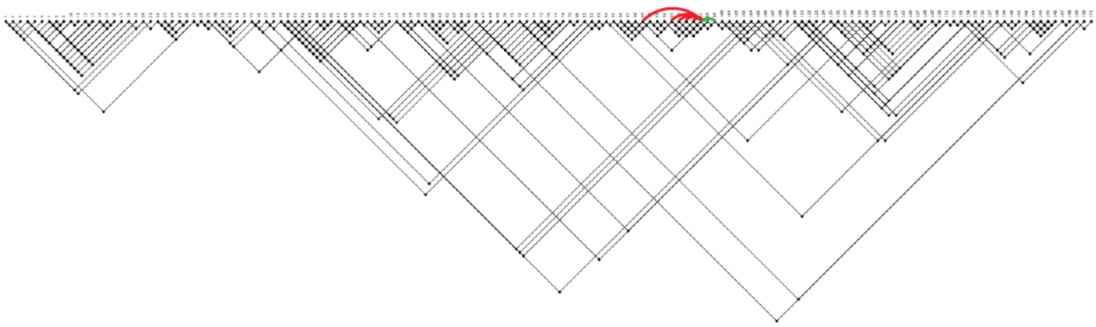

Figure 56. P7’s Linkograph

Eighth participant’s CM threshold is determined as four, and the one with most links is *Move44* with seven forelinks. His CM and its backlinks are given below:

M44: at this seating unit, I am going to use rising and decreasing small modules to unitize it and to give a waveform

BLs

M24: it [seating unit] can be partial

M27: then… a new module might start from here

M35: except that… this continuous part can be also split up

M43: except that… its [seating unit’s] lines can be modified… seaside… something comes from sea… reflecting the sea… waves… I can get rid of the hard lines…

Table 22 presents coded version of the moves:

Table 22. P8’s coded network

	M44	**M24**	**M27**	**M35**	**M43**
FBS	S’’’	S	S’	S’’	Be
IC	Form	Form	Form	Form	Form and Context

P8’s CM network, similar to P7’s, starts with the decision of designing a partite seating unit. Then again similar to the P7, P8 reformulates his idea (S → S’). Yet, at next idea (*M35*) he employs dialectical thinking and combines being *continuous* and *partial*. By this way, he reformulates (S’ → S’’) the idea again and expands his concept. At *M43* he assigns an expected behaviour to his design; *reflecting the sea*, and using dialectical thinking once more he contrasts curvy forms (by mentioning *waves*) with *hard lines.* At his critical move, *M44*, he employs dialectical thinking again and synthesizes (Be →S ’’’) the idea of *using rising and decreasing modules to unitize and to give a waveform*, which breeds seven FLs. Although his partial network is poor on addressing information categories such as Function and Human (user), as this critical idea (*M44*) causes a conceptual shift and becomes a creative insight, it affects almost half of his design process (Figure 57).

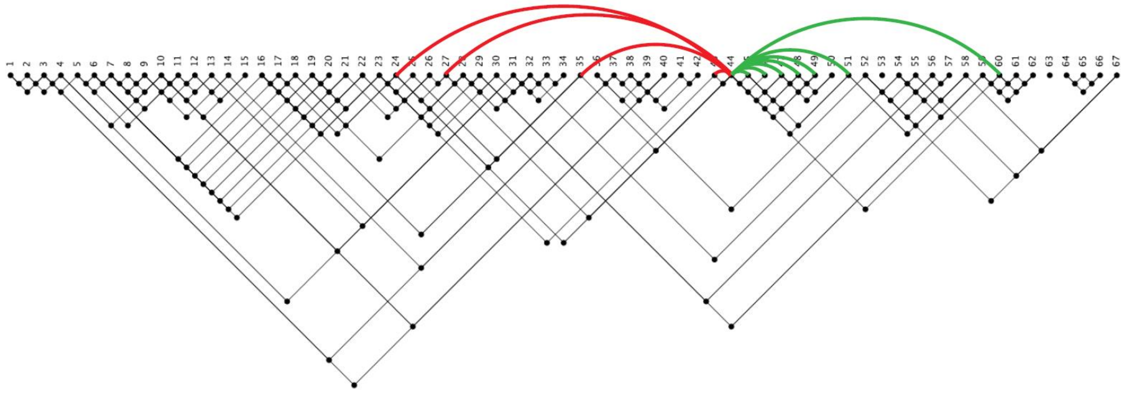

Figure 57. P8’s Linkograph

Ninth participant’s CM threshold is determined as four, and the one with most links is *Move90* with five forelinks. Her CM and its backlinks are given below:

M90: canopy…it [seating unit] can be a closed-space with the same functions of an open-space; a part for bicycles… they [users] can lie down, can sit down…

BLs

M12: at some point, the [seating] unit extends as much it can be for lying down
M15: even… at some points of the seating unit, there will be locks for bicycles
M62: if I use the form of a wave, exactly like this waveform [pointing the drawing], like a wave curl…
M75: Yes! Even I can use it [the wave curl form] as a canopy

Table 23 presents coded version of the moves:

Table 23. P9's coded network

	M90	**M12**	**M15**	**M62**	**M75**
FBS	S''	S	F	S'	Be
IC	Form	Form and Function	Function	Form and Context	Form and Context

When P9's coded network is examined it can be seen that her design process activities are reformulation (S → S') and synthesis (Be' → S). The syntactic analysis shows that she expands her concept by forming her design according to functions at *M12* and *M15*. And, at *M62* and *M75* she expands her concept by assigning a function to the *wave*form. At her CM, she goes back to the idea of the *canopy*, and she contrasts *open-space* and *closed-space.* By using dialectical thinking, she reframes her concept upon a contradiction, and she transfers the open-space functions to closed-space. By this way, she reaches to a conceptual shift which breeds five FLs (Figure 58). Although, it is questionable that if *M90* can be accepted as a creative insight as it does not have a significant effect on the overall design process, it can be said that it has impacts on idea generation productivity.

When her partial network is inspected, it can be seen that her partial design process covers most of the information categories. Yet, her partial process has lack of elements about Human (user) as well as relativistic thinking.

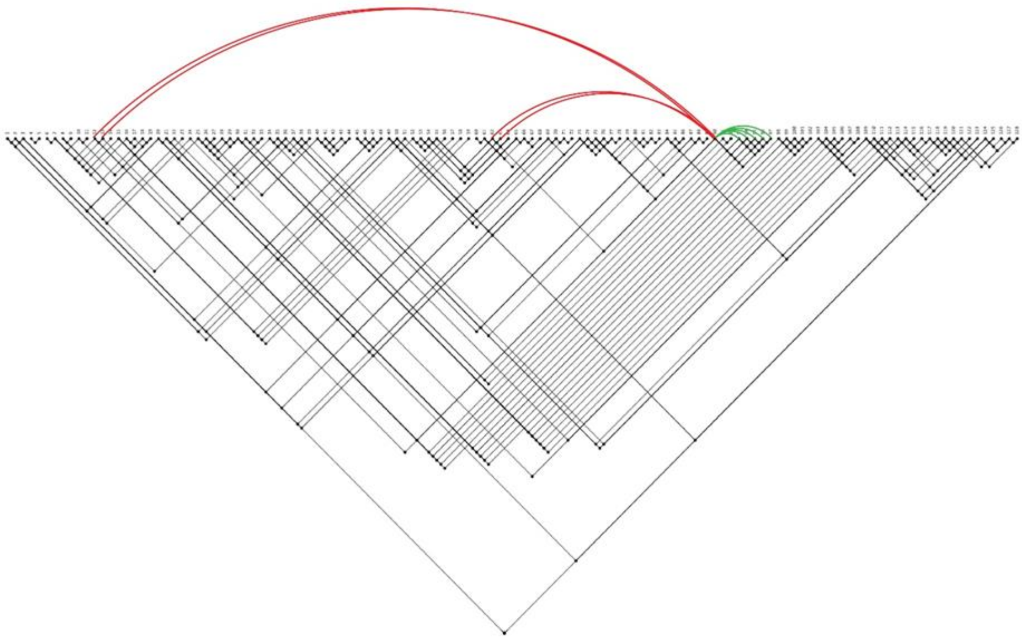

Figure 58. P9’s Linkograph

10th participant’s CM threshold is determined as five, and the one with most links is *Move21* with eight forelinks. Her CM and its backlinks are given below:

M21: there will be a curved canopy formed by linear elements

BLs

M8: instead of covering its [seating unit’s] back, it’s better to cover it with a canopy
M16: it won’t be covered from back, but will be covered by a canopy-like part
M18: like a bus stop… linear…
M19: No, not like a bus stop… but will have a shade
M20: which allows a visual connection with its [seating unit’s] back

Table 24 presents coded version of the moves:

Table 24. P10’s coded network

	M21	M8	M16	M18	M19	M20
FBS	S’’’	S	S’	Bs	F	Be
IC	Form	Form and Designer	Form	Form	Form and Function	Function

When P10’s coded network is examined it can be seen that her design process activities are analysis (S → Bs), formulation (F → Be), reformulation (S → S’) and synthesis (Be → S). Her partial network starts with a decision about form (*M8*), and at *M16* she slightly modifies her decision and expands her concept. At *M18* she *M19* she analyzes her idea by comparing it with a different type of product, and she compares and contrasts her design features and functions with *bus stop*’s form and function. By this way, at *M20*, she formulates her idea and also expands her concept once more. At her CM, *M21*, she synthesizes a creative insight by combining ideas of having a *canopy-like part* and *being linear* with a contrast, *curve*, by using dialectical thinking. By doing so, she also reaches a conceptual shift and an idea breeds eight FLs (Figure 59).

As seen in her partial design process, it can be said she is successful at using design activities and transforming ideas, as well as addressing information categories.

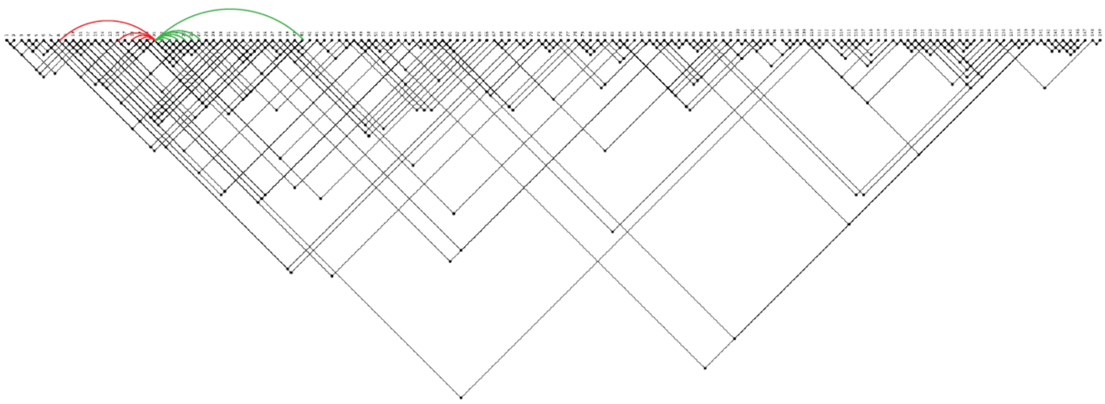

Figure 59. P10’s Linkograph

11th participant's CM threshold is determined as four, and the one with most links is *Move55* with six forelinks. Her CM and its backlinks are given below:

M55: Anyway there is such a thing… because one of them [seating unit components] is filled and the other one is empty… Ok, I won't render it [controlling the visibility] by height, but by fullness-emptiness

BLs

M44: Maybe I will do such a thing; I won't fill this part [pointing the drawing]
M45: And, I will set its [seating unit's] height like this [pointing the drawing]
M53: if we talk about this… height… the situation of not being able to see while passing behind [the seating unit]… yet, in the meantime… Yes, the people passing behind won't be able to see you but I want that they can see what kind of a seating unit is there
M54: Maybe which is why… does seeing [the seating unit] while passing by enough?
Table 25 presents coded version of the moves:

Table 25. P11's coded network

	M55	**M44**	**M45**	**M53**	**M54**
FBS	S	S	S'	Be	Be[i]
IC	Form and Designer	Form	Form	Form and Human (user)	Designer

When her network is inspected, it can be seen that her partial design process addresses Form, Human (user) and Designer information categories. She does not address function and behaviours of the structure at her partial design process. As seen from the coding, P11's network starts with two different statements on structure (form) (*M44* and *M45*). She reformulates (S → S') her structure and chooses a new expected behaviour (S' → Be) by using dialectical thinking; *be able to see* vs *not be able to see* (*M53*). Then, she continues with questioning herself in order to expand her concept (*M54*). Yet, at next design move, she shifts her concept by again employing dialectical thinking and re-forming her design with fullness-emptiness dichotomy. By this way, she synthesizes (Be → S) a new idea which becomes a creative insight and a CM with six FLs (Figure 60).

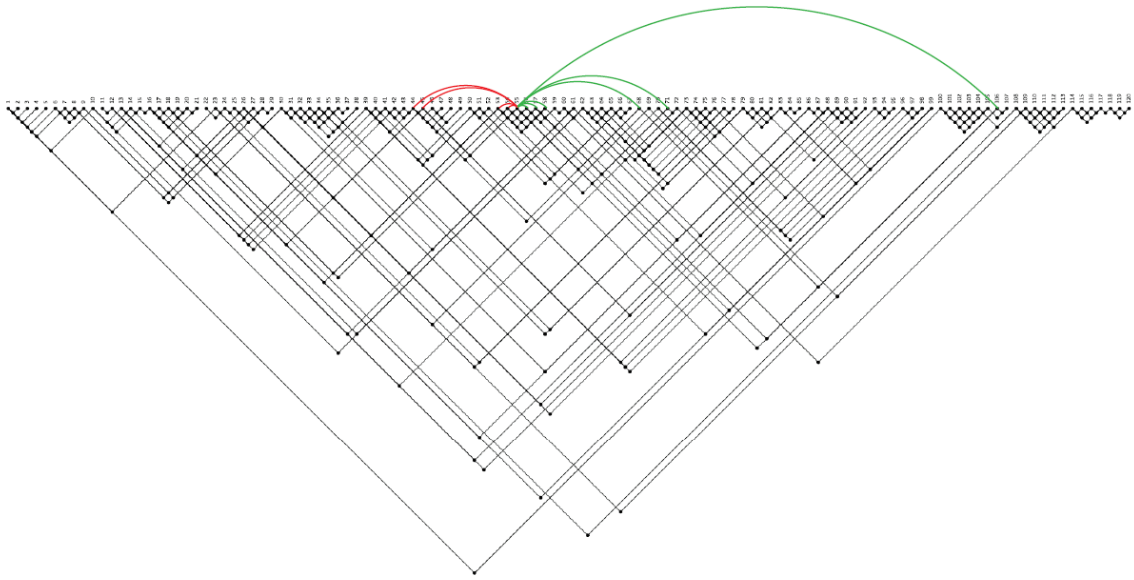

Figure 60. P11's Linkograph

12th participant's CM threshold is determined as four, and the one with most links is *Move59* with five forelinks. His CM and its backlinks are given below:

M59: or even a piece of metal will function [as a safety bar], or a piece of part that will be coated, like as in swings

BLs

M47: without a protection, users who sitting at the edges will be vulnerable, looks like they can fall into sea
M48: there [edges of seating unit] should be something for safety
M57: I should add something at the edges to block...
M58: like a solid brick wall… I mean a solid mass

Table 25 presents coded version of the moves:

Table 26. P12's coded network

	M59	M47	M48	M57	M58
FBS	S'''	Bs	S	S'	S''
IC	Form and Function	Form and Human (user)	Form and Function	Form and Designer	Form

At his partial design process network, P12's design activity is reformulation (S → S'). The partial network starts with a statement on the behaviour of the structure at *M47* and he defines a requirement related to it at *M48.* Later on, he employs formal thinking to expand his concept at *M57* and *M58*. At his CM, *M59,* he expands his concept once more. At the CM, it can be seen a dialectical thinking attempt as he contrasts *piece of metal* with a *solid mass*. Despite employing dialectical thinking, it remains a weak attempt to develop a creative insight. Yet, thanks to dialectical thinking, he manages to develop more FLs than BLs in that partial network (Figure 61).

Although his partial design process is weak on design activities and creating a creative insight, it is rich in addressing information categories. He manages to consider almost all categories except Context. This can be interpreted as addressing more information categories does not promote creativity in the design process.

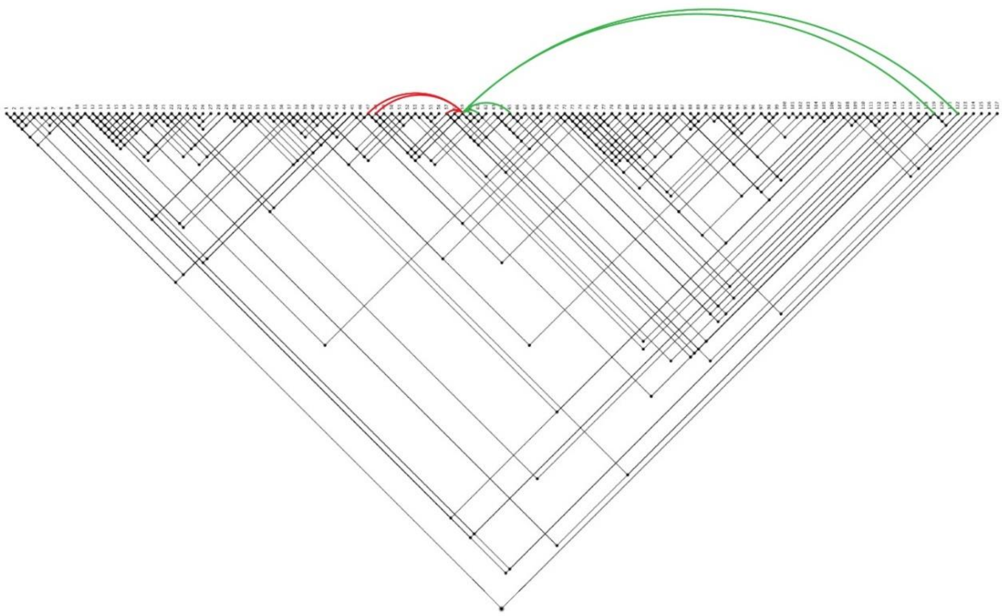

Figure 61. P12's Linkograph

13th participant's CM threshold is determined as five, and the one with most links is *Move26* with eight forelinks. Her CM and its backlinks are given below:

M26: I mean, it will be more than a seating unit and will serve other purposes. By this way, it can be differentiated… at least it can be more attractive for sitting on, instead of sitting on grass as a group or sitting on a portable chair

BLs

M3: [young people] prefer [to sit on] grass
M4: but I can design a seating unit they can use after the rain or the grass being watered
M11: They don't prefer to sit alone, but with friends
M20: Maybe something can be adapted or added to seating unit in order to attract more users…
M25: a thing designed with consideration of the activities of users will be added to this seating unit
Table 27 presents coded version of the moves:

Table 27. P13's coded network

	M26	**M3**	**M4**	**M11**	**M20**	**M25**
FBS	Be'	B^i	F	B^i	Be	S
IC	Form and Function	Form and Human (user)	Form, Function and Context	Form and Designer	Form and Human (user)	Form and Function

P13 starts with defining the behaviour of users (*M3*) and she develops an idea by assigning a function to her design (*M4)* and creates a new space of possible ideas. In this regard, she formulates her idea. At *M11,* she defines another behaviour of users in order to expand her concept. At *M20,* she defines an expected behaviour, *attracting more users* by changing the structure of her design. By doing so, she shifts her concept. At next design move (*M25*), she expands her idea through a synthesis (Be → S). Till at this point of her process, she uses relativistic thinking twice. Then, she reformulates her idea (S → Be'). At her CM, she uses dialectical thinking and compare and contrast her design idea with *sitting on the grass and/or on a portable chair*, as well as expanding her concept with the design decisions of *being more than a seating unit* and *serving to other purposes*. It is questionable that *M26* is a creative insight or not. Yet, *M26*'s constituents and itself are successful at generating FLs. Thus her design move becomes a creative insight into her design process and breeds eight FLs (Figure 62).

As her partial design process is relatively rich in design activities, it is also rich in addressing information categories. At her BLs, she addresses all of the categories and tries to come up with a design solution responds all of the design elements.

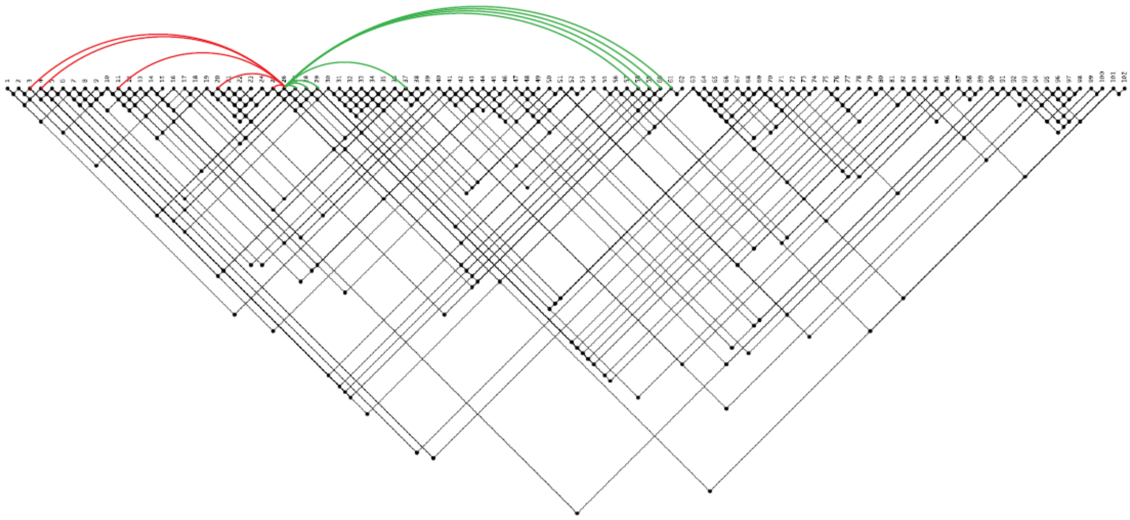

Figure 62. P13's Linkograph

14th participant's CM threshold is determined as five, and the one with most links is *Move61* with five forelinks. His CM and its backlinks are given below:

> *M61:* that's to say when it comes to a sitting unit there is no such thing that the users just sit there and watch the view... this sounds like a furniture design... I mean, it [seating unit] should be something can make difference… maybe a seating unit which can be transformed into space and can answer other functions than sitting
>
> BLs
>
> *M35*: units can be transformed, I mean not just for sitting

M36: maybe there will be a flatness, and an elevation around it [the gap]… people can use this elevation for sitting

M39: these units can be self-transformed

M52: it [seating unit] should answer different needs, not just sitting… how can it be?

M58: or… it can turn into something different as the units descend and rise in use

M59: for example elders can sit on it, but when there is no one sitting on, children can use it as a playground since it [seating unit] has elements descend and rise

Table 28 presents coded version of the moves:

Table 28. P14's coded network

	M61	M35	M36	M39	M52	M58	M59
FBS	Be'''	Be	S	Be'	F	Be''	F
IC	Function and Human (user)	Function	Form and Function	Function	Function	Form and Function	Form and Human (user)

When his network is inspected, it can be seen that his partial design process addresses Form, Function and Human information categories. Context and Designer categories are missing.

P14 starts to his partial design process network with a design decision on the expected behaviour of his design (*M35*). At next design move (*M36*) he shifts his concept by using dialectical thinking, *flatness* versus *elevation,* and synthesizes a new design idea (Be→S). At *M39* he expands his concept by reformulating his idea (S → Be'). At *M52* he expands his concept once more, but this time in regard to function. Then, he employs dialectical thinking and rephrases *flatness* and *elevation* as *descending* and *rising*, and expands his concept on both form and function manner (*M58*) which causes a new conceptual expansion at new design move, *M59*. At *M59* he employs relativistic thinking and combines the ideas he states at *M52* and *M58* into a more holistic design decision. At his CM, *M61*, he abstracts and formulates (F→Be) his idea given as an example at *M59.* By doing so, he expands his concept, comparing his design solution with *furniture design*, and introduces new notions such as *making a difference* and *transforming into a space.* It is questionable that *M61* is a creative insight or not as it is a kind of summarize and abstraction of the decisions stated at its BLs, and breeds fewer FLs than the count of its BLs. Yet, *M61*'s constituents, *M36* (with seven FLs) and *M59 (*with five FLs), can be accepted as creative insights, thus, it can be said that his partial process is creative in this manner (Figure 63).

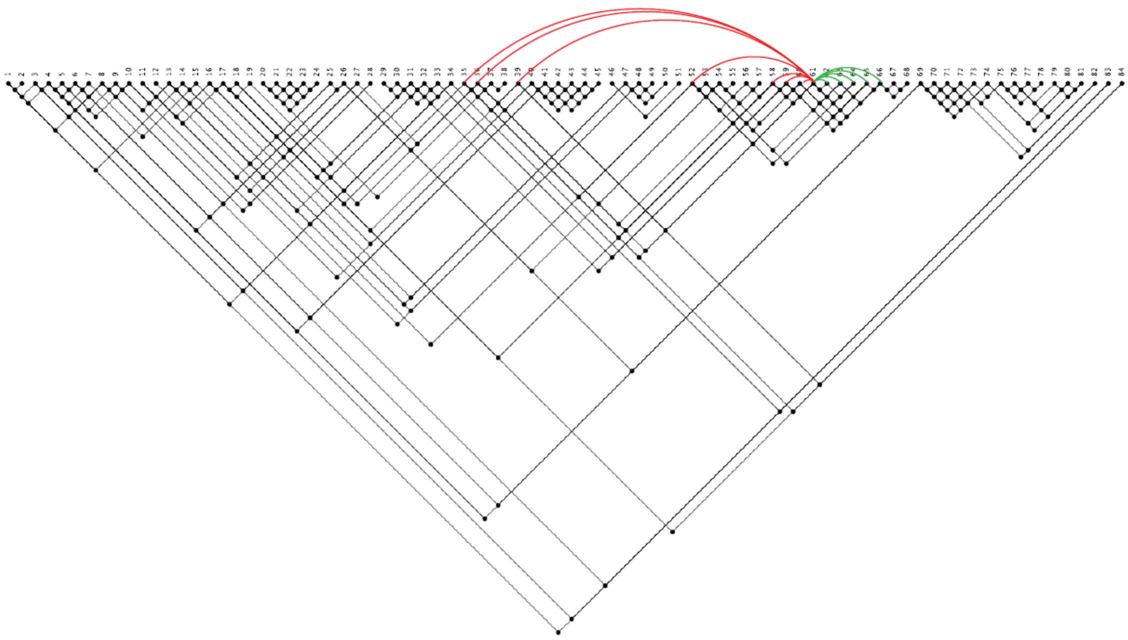

Figure 63. P14's Linkograph

15th participant's CM threshold is determined as six, and the one with most links is *Move26* with six forelinks. His CM and its backlinks are given below:

M26: other people also can pass through within collective scheme, that is, the parts can be integrated with the street.

BLs

M15: It [seating unit] shouldn't disrupt pedestrian traffic. In Kordon, there is a pedestrian traffic

M16: If I design something big, it can serve fragmentary

M17: By this way, people can also enter and exit [pass through]

Table 29 presents coded version of the moves:

Table 29. P15's coded network

	M26	M15	M16	M17
FBS	S	Be	S	Be[i]
IC	Form and Context	Context and Designer	Form and Function	Human (User) and Function

When P15's coded network is examined, it can be seen that his process is formed by two syntheses (Be→S) and addresses to all information categories. In addition to this, it can be said that he employs relativistic thinking as he builds his concept on human relations with the context and his design. At *M16,* he shifts his concept by introducing the idea of *serving fragmentary,* and at the following design moves, he expands his concept. Figure 64 presents his Linkography.

His partial design process differentiates from the other participants' partial design processes regards to focus group. All of the other participants who addresses Human information category focus on the actual users/seaters. But, P15 focuses on *pedestrians*, instead of users/seaters. Till *M15,* he identifies the users of the targeted area and their behaviours. He mentions that the users come to the targeted area as big groups. Then, at *M15* he states that the design *shouldn't disrupt pedestrian traffic.* In this regard, it can be inferred that he identifies two opposite groups; users vs pedestrians. Therefore, it can be said that he also employs dialectical thinking, but indirectly.

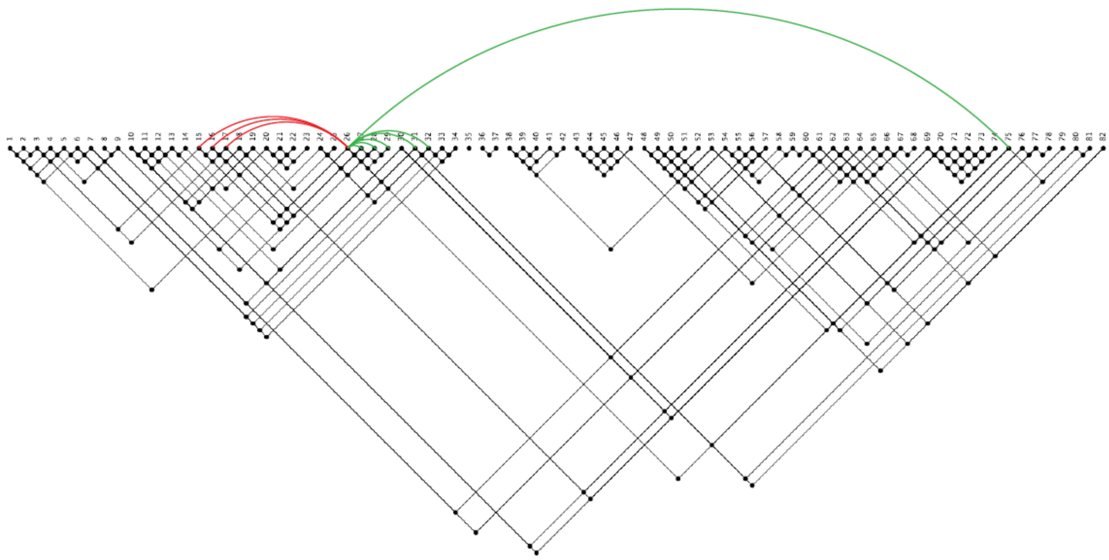

Figure 64. P15's Linkograph

16th participant's CM threshold is determined as four, and the one with most links is *Move51* with eight forelinks. Her CM and its backlinks are given below:

M51: it [seating unit] can be something integrated with the ground… condensing on the ground and expanding through the sea

BLs

M44: there is a feeling of depth...
M45: I mean, we all know... when we look at sea, we see a distancing in a perspective manner, I mean we feel a depth
M46: it can be a unit that can reflect that depth… how can I do this?
M48: Should I set a focal point for giving the feeling of depth

Table 30 presents coded version of the moves:

Table 30. P16's coded network

	M51	**M44**	**M45**	**M46**	**M48**
FBS	S'	Be^{i}	S^{i}	Be	S
IC	Form	Context and Designer	Context and Designer	Context and Form	Context and Form

P16's partial network starts with determining a feature of the context (*M44* and *M45*) and with a synthesis (Be→S). Later on, she decides to *reflect* the feature into her design (*M46*). By doing so she expands her concept. At *M48* she shifts her concept by synthesizing (Be→S) the idea of *setting a focal point.* At her CM, *M51*, she expands this concept by reformulating the structure (Be→S) and using dialectical thinking (*condense* vs *expand*). This thesis – antithesis – synthesis generates a creative insight which breeds eight FLs (Figure 65).

Although her partial design process can be accepted as creative, it is poor on design process activities and lacks on addressing Human (user) and Function information categories. Thus, it can be inferred that being rich in design process activities or information categories is not a necessity for having a creative design process.

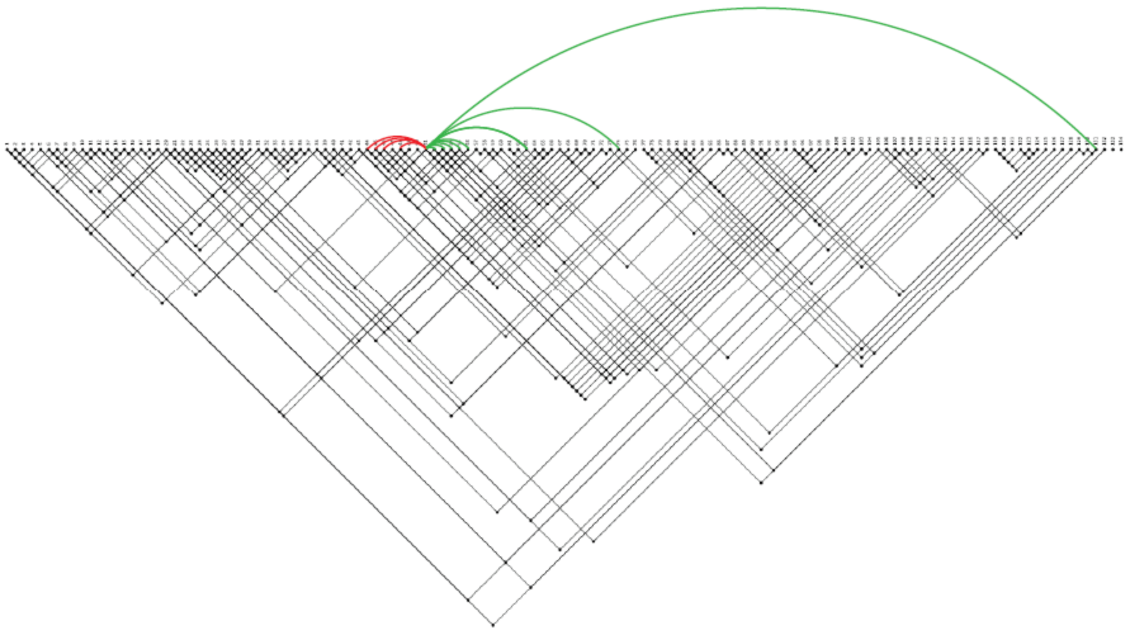

Figure 65. P16's Linkograph

17th participant's CM threshold is determined as five, and the one with most links is *Move10* with three forelinks. Her CM and its backlinks are given below:

M10: I think... going to the seaside to swim, and [lying down on] sand like a piece of a comfortable sun lounge... maybe… we shouldn't separate all our body from the sand, just a part of it...

BLs

M3: actually, now I think... beach... to swim... a seating unit for such a place
M4: at the beach, we don't have to sit on something
M5: but if we want to set apart ourselves from the granular structure in any case, maybe we can do it without too much elevation
M6: Let's think about it... It [body] might be somehow connected [to sand]...
M9: Let's think about it more... I guess providing comfort is also important…
Table 31 presents coded version of the moves:

Table 31. P17's coded network

	M10	**M3**	**M4**	**M5**	**M6**	**M9**
FBS	Be	Bs^i	Be^i	Be	Be'	F^i
IC	Form and Designer	Context	Designer and Context	Context and Function	Form	Function

P17 starts her partial network with defining the targeted environment she wants to design for (*M3*), and she comes up with the idea of there is no need to *sit on something* (*M4*) as a result of evaluation process (Bs → Be). Yet, at her next move (*M5*) she tries to set a concept for this evaluation. At *M6* she expands her proposed concept by expanding her design's expected behaviour. Then, with the aim of reaching a new conceptual transformation, she introduces a new requirement, *comfort* (*M9*). By this way, she creates a space for a formulation and extends her concept once more (F → Be). As seen, there is none synthesis in her partial design process. Also, there is a lack of employing postformal thinking. Thus, it has been believed that the poor idea generation activity is a consequence of synthesis and postformal thinking absence (Figure 66).

Although her partial process is unsuccessful on procreating a creative insight, it is successful in addressing information categories.

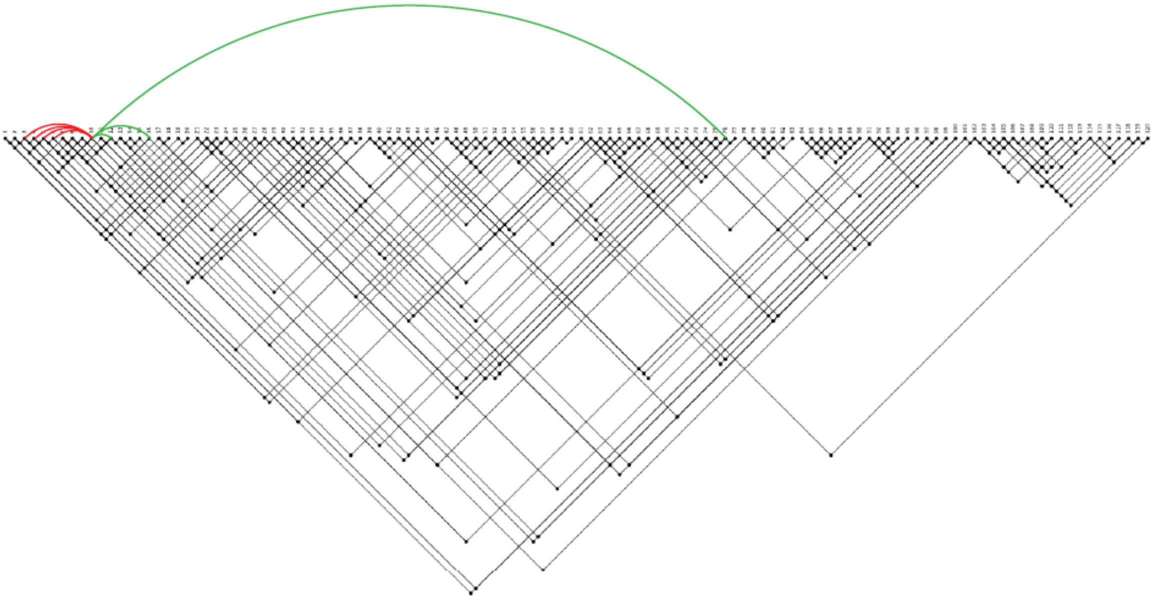

Figure 66. P17’s Linkograph

18th participant’s CM threshold is determined as five, and the one with most links is *Move46* with seven forelinks. His CM and its backlinks are given below:

M46: I'll make the angles sharper for interaction

BLs

M9: How can I provide interaction?

M19: interaction... crowd...

M21: there are different alternatives... what kind of alternatives? Yes... Sitting alternatives and interaction... a circular form allows [to interact]…

M27: sitting alternatives with faulted structures...

M28: I can create terraces here, angled terraces… terrace would be nice here…

Table 32 presents coded version of the moves:

Table 32. P18's coded network

	M46	M9	M19	M21	M27	M28
FBS	S''	F	F^i	Be^i	S	S'
IC	Form	Function	Function and Human (user)	Form and Function	Form	Form

P18's partial design process consists synthesis (Be → S), formulation (F →Be), and reformulation of structure (S → S'). He builds his concept of *interaction* (*M9*) and relates it to the *crowd (M19).* At *M21* he proposes a form, *circle*, to expand his concept and find a solution for *providing interaction.* Yet, at his next move, *M27*, he employs dialectical thinking and introduces *faulted structures* form as an antithesis to a *circular form*. By this way, he synthesizes a new idea and shifts his concept. His CM is the expanded version of the synthesis which breeds seven FLs (Figure 67). Regards to this, designing *angled terraces for interaction* becomes a creative insight into his design process.

When the information categories are inspected, it can be seen that he focuses on form and function, and mentions users once.

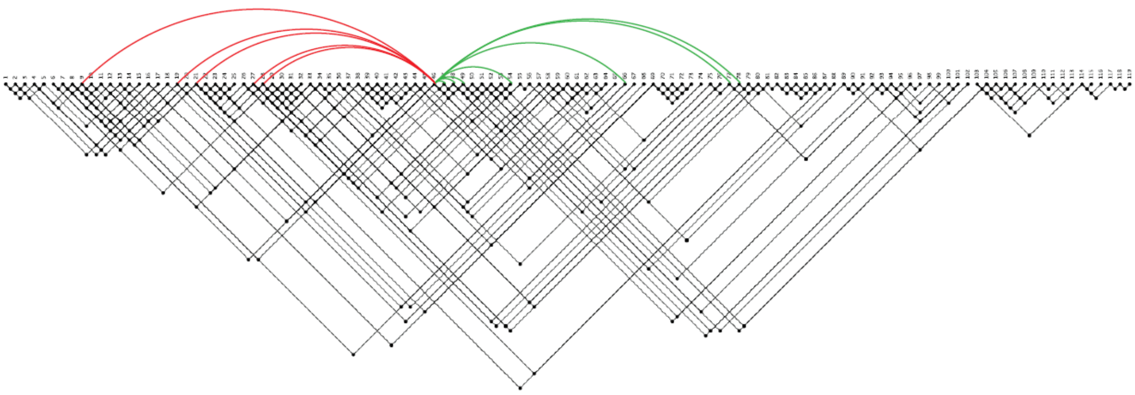

Figure 67. P18's Linkograph

19th participant's CM threshold is determined as five, and the one with most links is *Move76* with three forelinks. His CM and its backlinks are given below:

M76: Then... Maybe it shouldn't be angular but something else…

BLs:

M17: or at the same time, it may be short and be angular to allow stretching feet.

M72: I can deal with its [seating unit's] details... I mean people will ask themselves like "why I want to sit on this?"

M73: the place I sit on should satisfy me when I look at it by providing the perception of being comfortable

M74: Or maybe… even it [seating unit] looks uncomfortable, when I sit on it I can get relax

M75: Can I solve this with the form?

Table33 presents the coded version of the moves:

Table 33. P19's coded network

	M76	**M17**	**M72**	**M73**	**M74**	**M75**
FBS	S''	S	Be[i]	Be	Be'	S'
IC	Form	Form and Function	Human (user)	Form, Function, and Designer	Form	Form

P19's partial network starts with a design decision on the form (*M17*). At *M72,* in order to rationalize his design decisions, he tries to draw users' possible reactions by employing relativistic thinking. At next design move (*M73*) he expands his concept by providing a more extensive comment on user preferences. Then, he expands his concept once more and defines a requirement for his design (*M74*). At *M75* a question arises about the requirement and how it can be transferred to the design in the context of form which brings the decision of the form *shouldn't be angular*. It can be seen from the coded network he synthesizes (Be → S) an idea, yet it does not end up with a creative insight as his CM breeds only three FLs (Figure68).

At his partial design process, P19 addresses all information categories except context. Once more, it proves that generating critical insights is independent of ICs.

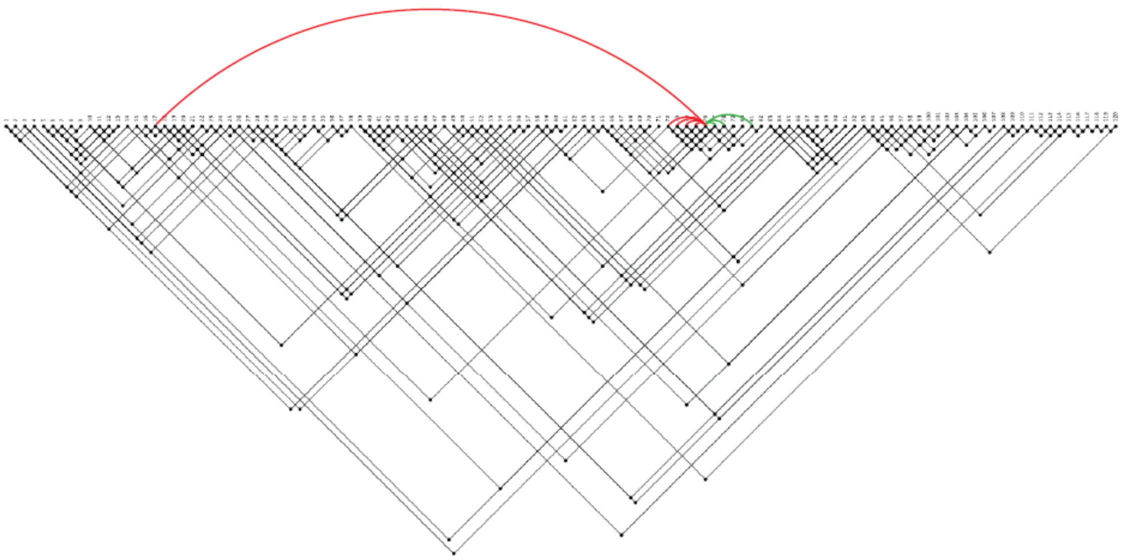

Figure 68. P19’s Linkograph

20th participant’s CM threshold is determined as six, and the one with most links is *Move149* with five forelinks. His CM and its backlinks are given below:

M149: Of course these forms may change later. Just a second... I did a mistake... I wanted to make this part an open-space, but also be shady. This green [plants] will provide a shade here

BLs:

M4: Here… there are always people seated, but there is a lack of shadow.
M105: Green... there is a lack of green
M128: The most important is the need for a shade, it shouldn’t be forgotten
M135: If we consider its [seating unit’s] orientation, we have to have a structure that is open from the front, so that a wide frame can be seen from Konak pier where we can see the city light.
M143: maybe without expanding the seating unit much…
M144: we can create a space for plants to get rid of the lack of green
Table 34 presents the coded version of the moves:

Table 34. P20’s coded network

	M149	**M4**	**M105**	**M128**	**M135**	**M143**	**M144**
FBS	F	Bs^{i}	$Bs^{i'}$	$Bs^{i''}$	S	S’	Be
IC	Form	Context and Human (user)	Context	Function and Designer	Form and Context	Form	Form and Function

At first four moves of the partial network, P20 determines the sub-problems and identifies the requirements, and at fourth move (*M135*) he also makes a design decision about structure. Then (*M143*) he makes another decision about the structure and reformulates (S → S’) it. After the reformulation, he assigns a new behaviour to the structure (S → Be) (*M144*). This move allows him to assign a new function which breeds five FLs (Figure 69). At his CM (*M149*) it can be seen that he positioning open-space as an anti-thesis of providing shade as it is a feature of closed or semi-closed space. Thus, it can be inferred that he employs dialectical thinking to find a medium to connect thesis and antithesis, and comes with the idea of providing shade by assigning a new function to *plants*. As being different than other participants, he prefers to provide shade by planting, not by adding a canopy. Regards to this, his CM becomes a creative insight.

His partial design process addresses all of the information categories. Yet it is poor on consisting design activities as he only does reformulation.

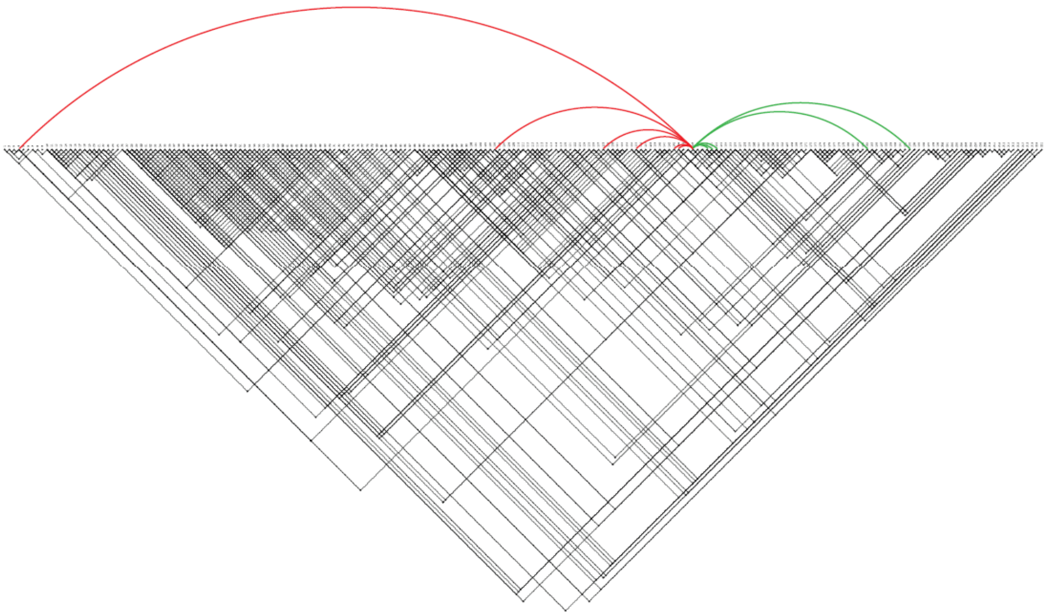

Figure 69. P20’s Linkograph

21st participant’s CM threshold is determined as six, and the one with most links is *Move24* with five forelinks. His CM and its backlinks are given below:

M24: and in the simplest case, the scenario can be like this… the fixed module defines a space

BLs:

M11: It can be assumed that the proposed modular units will respond to different usages.
M14: Thus, the module we are gonna design should allow different usages in this sectioned zone by having designated functions
M19: First and foremost we decided to make it [seating unit] modular, in order to answer different need and usages
M20: Likewise, it [seating unit] can be kinetic
M22: fundamentally, it [seating unit] will be fixed… like… maybe seating unit will have a fixed point
M23: but the mobility will be achieved by designing small modules which can be integrated [to fixed module]
Table 35 presents coded version of the moves:

Table 35. P21's coded network

	M24	M11	M14	M19	M20	M22	M23
FBS	Be	F	F'	S	S'	S''	S'
IC	Form and Function	Function and Designer	Function and Context	Form and Function	Function	Form	Form and Function

P20's partial network starts with defining a requirement (*M11*). At his next three moves (*M14, M19* and *M20*) he expands his concept regards to Function and Form. At *M22,* he employs dialectical thinking and introduces *being fixed* against *being kinetic.* From *M23* it can be inferred that he does not choose one of them but combine two opposition by using form/structure as a medium. In this way, he creates a sub-solution for defining *sectioned zones* (*M14*) by creating space with using *fixed modules*. Also, he generates a creative insight which breeds five FLs (Figure 70)

As seen at the coded network, his partial design process is relatively rich in addressing information categories, yet when it comes to design activities, it can be said it is poor as the partial network is dominated by reformulations (S → S', S → Be).

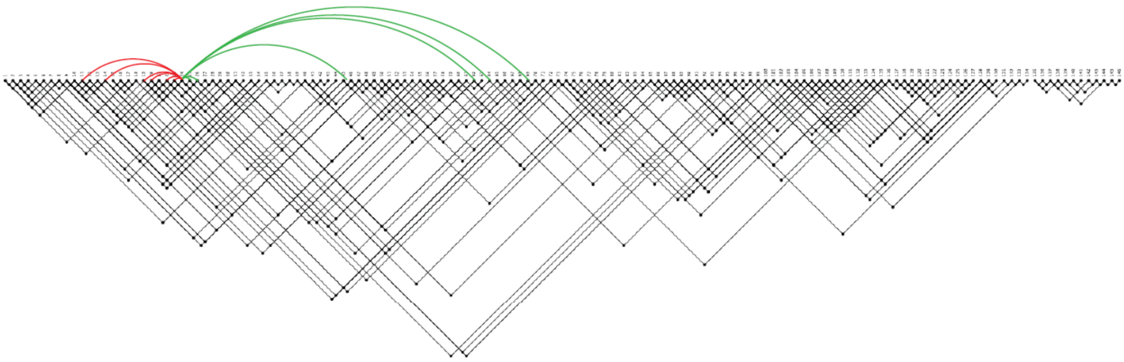

Figure 70. P21's Linkograph

22nd participant's CM threshold is determined as five, and the one with most links is *Move57* with six forelinks. His CM and its backlinks are given below:

M57: I will try to design spaces for private and public usages on it [the spline]

BLs

M24: we can use it [seating unit] when we are alone

M25: or public…

M32: and maybe… on this seating unit, that I am trying to design now, I can provide both publicity, I mean public interactions

M33: and privacy, I mean spaces for individual usages, private to me…

M34: yes… when I think like that… I imagine I have a curve. I imagine I am drawing a spline in Photoshop or AutoCAD

Table 36 presents coded version of the moves:

Table 36. P22's coded network

	M57	**M24**	**M25**	**M32**	**M33**	**M34**
FBS	Be	F	F'	F''	F'''	S
IC	Form and Function	Human (user)	Human (user)	Human (user) and Function	Human (user) and Function	Form

P22's partial network starts with defining use case, *alone* versus *public* (*M24, M25*). Although he positions this two states as opposites, he also uses them to define possible user preferences. Therefore, it can be said his approach is both dialectical and relativistic. Then, he starts to expand his concept with a decision on combining two contrasting states, *public* and *private* ((*M332* and *M33*). Thus, it can be said, he builds his concept on dialectical thinking mainly. At *M57,* by reflecting *public* and *private* dichotomy to the form (*M34*) by reformulating (S → Be) and shifting the concept, he reaches to a creative insight which breeds six FLs (Figure 71).

Although he combines two postformal thinking modes during his partial design process and reaches to a creative insight, his design activity remains with just reformulations (S → Be), and he addresses to three-fifths of the information categories.

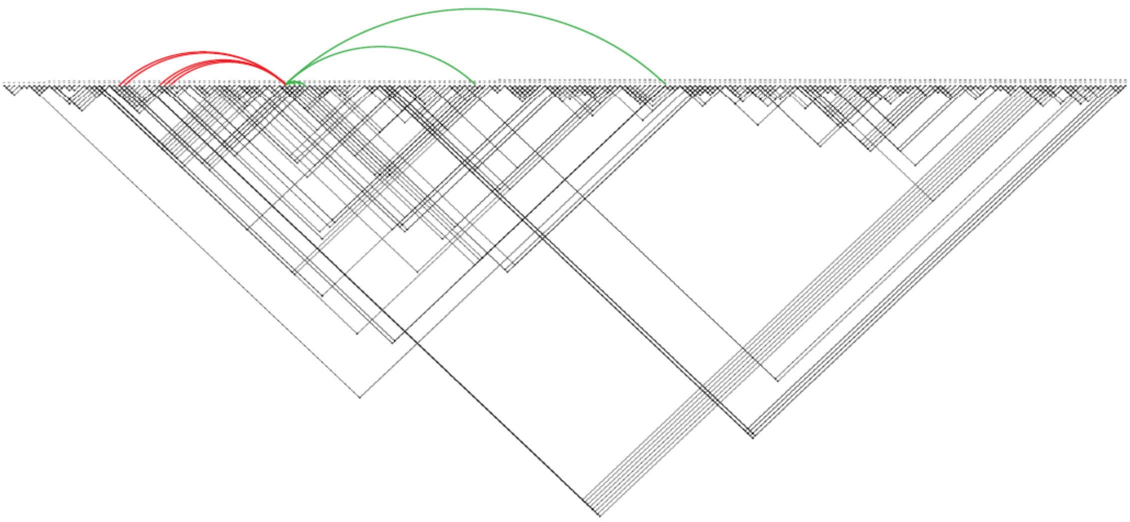

Figure 71. P22's Linkograph

23rd participant's CM threshold is determined as six, and the one with most links is *Move63* with ten forelinks. His CM and its backlinks are given below:

M63: Ok then! Instead of moving only at X and Y coordinates, maybe I can think about a movement at Z coordinate too. How can I [seating unit] perform at Z coordinate?

BLs

M19: This [designing for private and public usages] will determine functions also
M22: This is about how the mechanism of my design [seating unit] should be… it's a kind of base…
M27: hmmm… kinetic seating unit…
M53: There might be kinetic spaces… hmmm… what kind of kinetic spaces?
M54: mechanic… I should think it [seating unit] as mechanic,
M62: I mean it [seating unit] should be proteiform, the things [seating units] can turn into open, semi-open or closed [space] would provide much more advantages.

Table 37 presents coded version of the moves:

Table 37. P23's coded network

	M63	M19	M22	M27	M53	M54	M62
FBS	Be'''	Be^i	S^i	F	Be	S	Be''
IC	Function	Function	Form and Function	Function	Form and Function	Function	Form and Function

P23's partial starts with identifying a rule for *determining functions* which is a product of dialectical thinking (*private* and *public*). Subsequent to this decision, he synthesizes (Be → S) an idea (*M22*), and expands his concept by choosing a new function for his design (S → F) (*M27)*. At *M53* he expands his concept once one with formulation (F → Be) and at the following move goes back to *being mechanic* decision and repeats his synthesis once more. At *M62*, he employs dialectical thinking again (*open, semi-open, closed spaces*), and shifts the concept by reformulation (S → B). At his CM, *M63*, he assigns coordinates (*x, y, z)* to movements which will *create open, semi-open*, *closed spaces*, and develops a creative insight which breeds ten FLs (Figure 72).

His partial design process focuses just on Form and Function ICs.

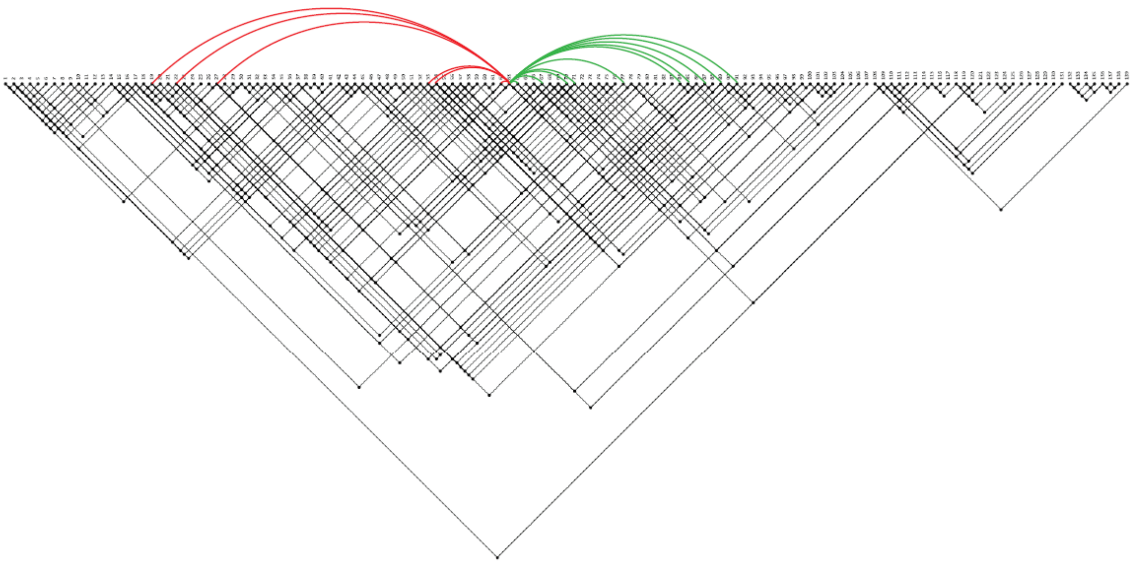

Figure 72. P23's Linkograph

24th participant’s CM threshold is determined as six, and the one with most links is *Move143* with six forelinks. His CM and its backlinks are given below:

M143: Thus, I can arrange the pier part for children a bit more

BLs

M7: If we think about the Gülbahçe pier...
M8: At that wooden pier, the view is beautiful, you can see both bays... I will design [seating unit] for that place
M9: Even, when we go to the edge of the pier, we are literally in the sea
M43: Time to time children come there [to the pier]
M51: Maybe I can limit certain areas of the space… It will be like a seating unit but a little more spatialized
M53: Maybe children will play with sand
M74: In some cases, it is difficult for an adult to sit on a child seat
M78: and for a child, it’s the opposite, s/he can fall off when climbing on it [seat]
M138: The water [sea] is shallower on that side of the pier… I mean really, really shallower
M140: but the user of that part [the particular side of the pier] may be children because the sea is shallow there
M141: The water there [sea surface height] does not exceed the knee height, so the children can also play with the water here

Table 38 presents coded version of the moves:

Table 38. P24’s coded network

	M143	**M7**	**M8**	**M9**	**M43**	**M51**
FBS	S	S^{i}	Bs^{i}	$Bs^{i'}$	Be^{i}	S
IC	Form	Context	Context and Designer	Context	Human (user)	Form and Function
	M53	**M74**	**M78**	**M138**	**M140**	**M141**
FBS	$Be^{i'}$	$Be^{i'}$	$Be^{i''}$	$Bs^{i'''}$	$Bs^{i''''}$	$Be^{i''''}$
IC	Human (user)	Human (user)	Human (user)	Context	Context and Human (user)	Context and Human (user)

P24’ partial network starts with an analysis (S → Bs) on context (*M7* and *M8*), and he expands his analysis further (*M9*). At M43, he introduces a new potential user variable. This design move raises an opportunity for a synthesis (Be → S) and for a decision on form and function (*M51*). By this way, he reaches a conceptual shift. At next design move (*M53*) he describes a use case for children and expands his concept once more. At *M74* (which breeds 20 FLs) and *M78* (which breeds 16 FLs), he compares and contrasts the possible usage limitations by employing both relativistic and dialectical thinking (adult vs child). Later, he further analyses the context (*M138*), evaluates (Bs ↔ Be) his decisions about the relations of users and context (*M140* and *M141*). Then, he expands his concept once more with a synthesis (Be → S), and he generates a CM which breeds six FLs (Figure 73). It is questionable that whether his CM (*M143*) is a creative insight or not as it does not cause a conceptual shift, yet it can be said his partial network is successful on idea generating and networking, and on addressing to information categories as well as having creative insights.

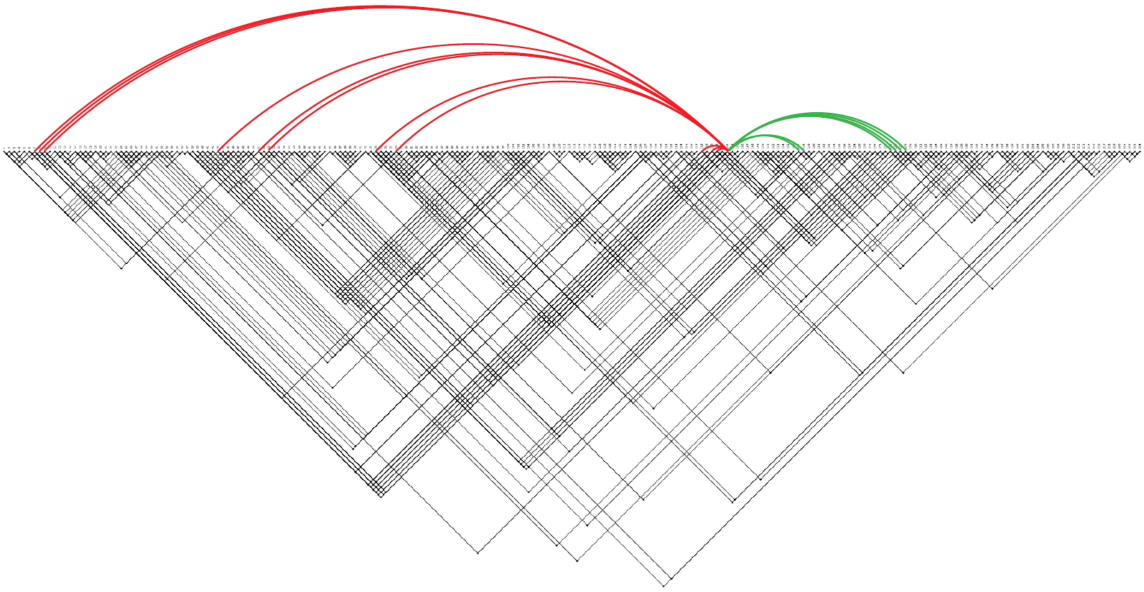

Figure 73. P24’s Linkograph

25th participant’s CM threshold is determined as seven, and the one with most links is *Move20* with thirteen forelinks. Her CM and its backlinks are given below:

M20: a seating unit goes in a spiral shape in Kordon...

BLs

M8: Now... as the seating unit... Hmmm... it won’t be just a seating unit. Because, just like a bench, limited, wouldn’t be nice... it is an ordinary good. Thus, if we design it [seating unit] in an uncommon way, more people would prefer to sit on it.

M11: For example, a bench has only one direction, and face with only one view... the view might be beautiful but it’s the only one…

M14: So, then the concept should be interaction… But this interaction shouldn’t be in only one direction…

M15: Actually, it’s simple, even an oval form allows users see each other and communicate more easily and comfortably. Maybe, it’s better to draw exactly like this, this [form] may provide more comfort on seeing each other

M17: If its [bench] direction were different, people might prefer more to sit on

M18: Thus, it [seating unit] shouldn’t be in a single row

M19: It [seating unit's form] should twirl like this, and allow others to sit on too while I am sitting here [pointing a part of seating unit]… without bothering each other

Table 39 presents coded version of the moves:

Table 39. P25's coded network

	M20	**M8**	**M11**	**M14**
FBS	S'''	Be	Bs^{i}	F
IC	Form	Human (user) and Form	Form	Form and Function
	M15	**M17**	**M18**	**M19**
FBS	S	Be	S'	S'
IC	Form, Function and Human (user)	Form and Human (user)	Form and Designer	Form and Human (user)

P25 starts her partial network with a decision on the requirements and draws a concept (*M8*). Later on, she evaluates (Be ←→ Bs) her decision by comparing it with *bench* and expands her concept by determining the limitations (*M11*). Here, she employs dialectical thinking as she positions *bench* as thesis and her design as antithesis. This action leads her to set another criterion for her design, and she introduces *interaction* criteria to her concept (*M14*). Related to her criteria she proposes a form which can meet the requirements at *M15*. By revisiting the limitations she mentions before, she reformulates (S → Be) her concept (*M17*) regards to expected behaviours. At the following design move (*M18*), she generates a new synthesis (Be → S). Since the synthesis is raw, she employs dialectical thinking once more and positions *twirling* as an antithesis to *straight*. By this way, she shifts her concept, and reformulate the structure. At her CM, M25, she reformulates her synthesis once more and reaches to a creative insight which breeds thirteen FLs and shapes her design process (Figure 74).

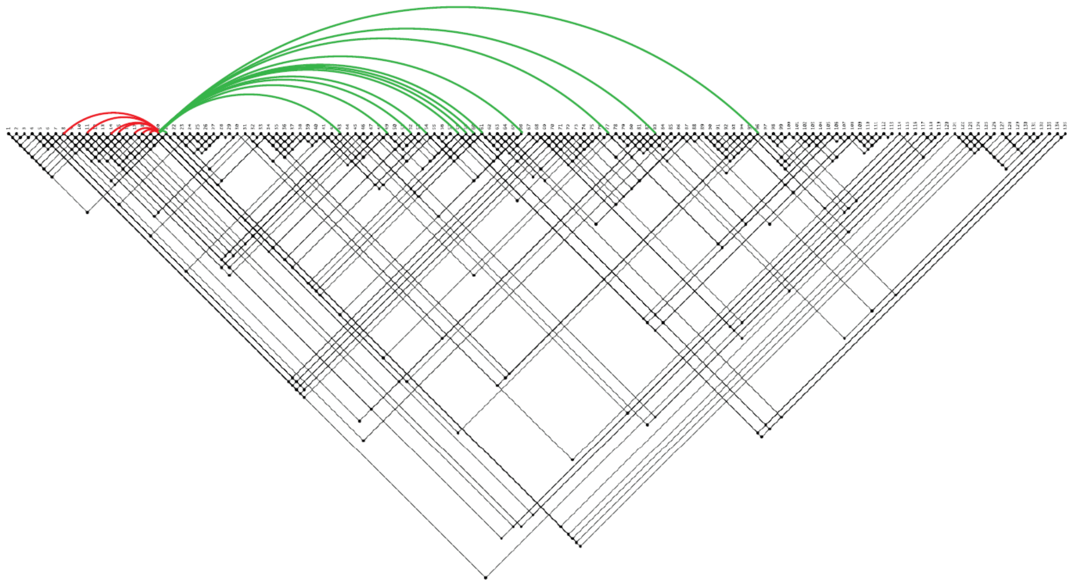

Figure 74. P25’s Linkograph

Table 40. Syntactic analysis of participants' partial networks

Participant	Relativistic Thinking	Dialectical Thinking	Conceptual Expansion	Conceptual Shift	Creative Insight	Analysis	Formulation	Reformulation	Evaluation	Synthesis
P1	✓	✓	✓	✓	✓				✓	✓
P2		✓	✓	✓	✓					✓
P3			✓					✓		
P4			✓					✓		
P5			✓							
P6		✓	✓	✓				✓		✓
P7			✓			✓		✓		
P8		✓	✓	✓	✓			✓		✓
P9		✓	✓	✓	✓			✓		✓
P10		✓	✓	✓	✓		✓	✓		✓
P11		✓	✓	✓	✓			✓		✓
P12			✓					✓		
P13	✓	✓	✓	✓	✓		✓	✓		✓
P14	✓	✓	✓	✓	✓		✓	✓		✓
P15	✓	✓	✓	✓	✓					✓
P16		✓	✓	✓	✓			✓		✓
P17			✓				✓	✓		
P18		✓	✓	✓	✓		✓	✓		✓
P19	✓		✓					✓		✓
P20		✓	✓	✓	✓			✓		
P21		✓	✓	✓	✓			✓		
P22	✓	✓	✓	✓	✓			✓		
P23		✓	✓	✓	✓		✓	✓		✓
P24	✓	✓	✓	✓	✓	✓			✓	✓
P25		✓	✓	✓	✓			✓	✓	✓

Table 40 sums up the syntactic analysis of participants' partial networks. Information categories are excluded as it has been concluded that information categories do not affect creative insight generation.

As seen from the Table 40, 32% of the participants applied relativistic thinking, 72% of the participants applied dialectical thinking, 5% of the participants applied both relativistic and dialectical thinking, and in total 76% of the participants applied post-formal thinking during their partial design processes. It is seen that 94% of the participants who applied dialectical thinking generated a creative insight and 83% of the synthesizing activity results with a creative insight.

As seen from the Table 40, solely applying relativistic thinking generates synthesis. Yet, as only one participant of the experiment solely applied relativistic thinking, this result cannot be accepted reliable and needs further research. But, because of many of the participants solely applied dialectical thinking, it would be reliable to draw a conclusion about the correlation between dialectical thinking and synthesis productivity. As seen from the Table 40, 83% of the participants who applied dialectical thinking during their partial design processes generated a synthesis.

When it comes transformation on a conceptual level it has seen that all of the participants generated conceptual expansion, and 76% of the participants generated conceptual shift. All of the dialectical thinkers generated both conceptual expansion and conceptual shift. Addition to this, 94% of the participants who generated a conceptual shift also generated a creative insight.

The occurrence of FBS ontology transformation types vary as: 8% of the participants had analysis, 24% of the participants had formulation, 76% of the participants had reformulation, 12% of the participants had an evaluation and 64% of the participants had synthesis. It can be said that reformulation is the dominant transformation type, and the synthesis is the second dominant one. 85% of the participants who had synthesis and 65% of the participants who had reformulation also generated creative insight. It is concluded that the data is insufficient to investigate the relations between creative insight generation and analyses, formulation and evaluation. The data showed that there is none direct relation between post-formal thinking and occurrence of FBS ontology transformation types, except synthesis. It is found that 83% of the participants who applied dialectical thinking generated a synthesis, and 84% of the participants who applied postformal thinking generated a synthesis.

CHAPTER 5

CONCLUSION

Creativity has been always one of the core topics of design research. Many design researchers tried to shed light on the occurrence of creativity by investigating the designers' personal characteristic, design processes, products and effects of environment on creative performance. In its contribution to the vast literature on design creativity and design cognition, this thesis presents a better and extended understanding of the role of formal and postformal thinking in the creative design process.

As given detailed in the Creativity and Design Process section, according to combination-theorists (e.g. Boden, 1998, Koestler, 1964, Mednick, 1962) the creative insight is the product of a fusion of two different conceptual spaces. Thus, the quality of constituent matrices of the creative insights, and the thinking modes applied during the process have significant impacts on the creative performance. According to researchers (e.g. Dietrich, 2004; Mednick, 1962, Schank and Cleary, 1995), the quality of constituent matrices depends on the conceptual spaces they belong to; the more varied the better. Yet, multivariate syntheses demand advanced thinking modes (Commons and Ross, 2008; Piaget, 1952; Santrock, 2011). As given detailed in the Adult Cognitive Development section, the adulthood thinking modes are determined as formal thinking, relativistic thinking and dialectical thinking (see Arlin, 1975; Basseches, 1984; Kramer, 1983; Piaget, 1952; Riegel, 1973; Sinnott, 1984). These three thinking modes provide different reasoning skills to operate at complex systems. To be able to do a multivariate synthesis, one should apply relativistic and/or dialectical thinking as these two thinking modes allow individuals to solve ill-defined, multidimensional problems (Commons and Rose, 2008). Therefore, it was hypothesized that finding a creative solution to an ill-defined design problem requires advanced, rather than formal thinking skills, which are linked with post-formal thought stages, and creative performance has strong connections with the thinking types of the post-formal process; i.e. relativistic and dialectical. In order to evaluate the hypothesis, the two legs methodological approach was adopted. With a deductive approach, the quantitative analysis focused on the correlations between participants' thinking modes and design processes' idea generation entropies; and with an inductive approach, the syntactic analysis focused on the quality of constituent matrices of the creative insights, and the thinking modes applied during the partial design processes. To do so, a vast data is gathered through Social Paradigm Belief Inventory (SPBI) and Think-aloud Protocols and analysed through Linkograpy, Pearson's Correlation Coefficient Method and FBS Ontology.

Quantitative Analysis of the Protocols showed that there is a strong positive relation between dialectical thinking and creative design process, whereas formal thinking has a strong and relativistic thinking has weak negative effects on the creative design process.

In this study, it was expected that the participants at post-formal thinking levels would obtain good link index and critical move scores as they would create more links in order to find creative solutions to ill-defined design problems. To investigate this, the participants' SPBI scores were compared with the total number of links created during the design sessions. The results showed that people with high SPBI scores tend to have high link index values, which seems to indicate post-formal thinkers tend to create more ideas and links, and thus tend to be creative. Even if the previous unrelated ideas are contradictory, as high SPBI scorers are better at perceiving actual or potential relations between previously unrelated matrices of thought, the high scorers might have more ideas to link each other. Similarly, it has been seen that having a higher SPBI score has a significant relationship with having a high number of critical moves. This might be because post formal thinkers are aware of their inquiry process, they tend to build denser linking structures by linking as much as design moves to each other, in order to verify their thinking process.

As expected, the research has shown that formal thinking has a negative correlation with the productivity of linking. Also, results showed that the formal thinking has a strong negative correlation with both link index and critical moves. These results echo previous works in which formal thinking was negatively related to creativity (Blouin and McKelvie, 2012; Yang et al., 2010; Wu and Chiou, 2008). As formal thinkers tend to work in closed systems, creating more links might actually be challenging to their thought process. Hence, they are unable to break open common beliefs and create more creative, unconventional solutions.

For this study, a weak positive correlation between link indexes and relativistic thinking was expected. However, the results show a weak negative correlation with creativity. Similarly, the relativistic thinking showed weak correlation with critical moves. Although relativistic thinking is a thought process within the postformal thought stage, and as such should be positively correlated with creativity, it is also a competitor of dialectical thinking, which is even more strongly correlated with creativity. Indeed research results indicate that relativistic thinking might have a regressive effect on creativity by inhibiting dialectical thinking. As the Relativistic thinkers tend to create new ideas by linking knowledge units within a dependently changing thought process and cannot work with multiple perspectives at once, they might suffer from the inability of well structuring their thought process.

As it was expected, the correlations between link indexes and dialectical thinking showed a significant positive relationship. Similarly, as expected, results showed that there is a strong positive correlation between dialectical thinking and critical moves. This could indicate that people who have the ability to link knowledge across multiple perspectives at once and to comprehend contradictions tend to be more creative. Also, as they are able to connect more independent knowledge chunks and able to work with multiple perspectives at once, they are better at structuring their thought processes and creating a possible novel and applicable potential solutions.

From these results, it is possible to end up with a conclusion that dialectical thinking is more useful for finding more novel solutions to design problems and being creative, whereas relativistic thinking and formal thinking have a negative relationship. The results obtained during this research also show that SPBI scores may be used as pre-determinants of individuals' creativity as they showed strong relationships with idea generation productivity and linking activity.

As seen in the protocols, all three thinking modes are essential for a design process. Because of design problems involves a different kind of design variables, knowledge domains and reasoning modes, the three thinking modes have a different type of roles. Analyses of the protocols revealed that designers tend to apply formal thinking while dealing the technical aspects of the design problems because technical problems are well-defined and their solutions belong to closed systems. When it comes to the aspects of users' preferences, cultural and social representational value sub-problems, it is seen designers tend to adopt relativistic thinking. The participants mostly applied relativistic thinking when pinpointing the users' moral principles, usage preferences and interaction with others and the design. The pattern of the protocols exposed that designers tend to apply dialectical thinking to generate a concept and/or synthesize a solution from the sub-solutions, as well as to determine and overcome contradictions.

Syntactic analysis of the protocols verified that the occurrence of creative insights strongly connected to dialectical thinking. With the highest percentage, the dialectical thinking was the most common thinking style in critical move generation. Addition to this, all of the dialectical thinkers generated more than five more ideas rooted in their critical moves.72% of the participants applied post-formal thinking during their partial design processes. Results showed that 83% of the participants who applied dialectical thinking generated a synthesis and 94% of the participants who applied dialectical thinking generated a creative insight, and all of them reached to a conceptual shift. Thus, it can be said applying dialectical thinking guarantees a transformation on the concept and provides a high potential for generating a creative insight in the design process. These results also verify the results of the correlations between dialectical thinking and linkographic entropies. As mentioned before, creativity occurs when two or more unrelated matrices merged into one. With keeping this in mind, it can be said that designers might be preferring to generate a synthesis by comparing, contrasting and connecting thesis and anti-thesis to generate a synthesis. Thus, they might unconsciously apply dialectical thinking to reach a creative insight.

Although according to Koestler (1964) the creative insight is a product of an intellectual synthesis, it has been seen that 83% of the synthesizing activity results with a creative insight. Yet, it should also be considered that the definitions of the Koestler's *synthesis* and FBS ontology's *synthesis* might be different than each other, and Koestler might refer all kind of FBS ontology transformations as *synthesis*.

To sum up, it is concluded that although all the three thinking types have a role in the design process, dialectical thinking has a special role in creativity and on the occurrence of creative insights. It can be said to be more creative, designers may want to focus on *thesis-antithesis-synthesis* model and on determining contradictions to synthesize a more unconventional solution.

5.1. Contribution to Knowledge and Implications

This thesis contributes to knowledge by identifying the roles of adulthood thinking types on the creative design process and captures the structure of reasoning during the creative insight generation through examining the design session protocols. Regard to this, this thesis contributes to the design, creativity, and cognitive research literature. By providing a better and extended understanding of the roles of formal and postformal thinking types in the creative design process, this thesis also provides an opportunity for applying these thinking types consciously in order to be more creative.

The insights gained from this research can also be implemented to design in order to foster creativity during the design process. Educators may interest to the important points on the relations of the dialectical thinking usage and the occurrence of creative insights in order to develop a curriculum that promotes the creativity of design students by promoting cognitive skills.

5.2. Future Research

Future research may investigate the roles of relativistic and dialectical thinking independently from formal thinking, in order to further assess why relativistic thinking negatively correlated with linking productivity and creativity. To do such, researchers may need a different thinking style measurement, with just focusing on relativistic and dialectical thinking, than SPBI.

Analyses and evaluations of the results revealed some interesting patterns in the participants' design processes' verbal data which can be a good base for developing a method for creative problem-solving. Hence, a new research can be conducted in order to investigate these patterns more. If the patterns can be confirmed to be a good base for a new creative problem-solving model, this model can be implemented to design education in order to promote students' creative skills by fostering third-party factors' efficacy.

5.3. Limitations

The major limitation of the thesis arose from the limitations of think-aloud protocols. Because of the nature of the method, it was hard to capture undeformed and undistorted verbal reports of the thought processes. Also, because there was no other empirical data to evaluate the validity of the verbal reports, the protocols were pretty open to different interpretations which caused disaccord between coders time to time.

Because of the segmenting and the coding of the verbal data was labour intensive and took a significant amount of time, judging the verbal data demanded a firm and steady concentration, as well as multiple cross-checks between the judgements. Especially, some verbalisations, such as incomplete sentences, were pretty open to different interpretations. Hence, it is possible to question segmentation and codes of this kind of verbalisations by speculating on the irreconcilability between them.

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