# NATURE INSPIRED DESIGN PARADIGMS FOR DESIGN IDEATION: A STUDY ON PACKAGING DESIGN

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

NUR YILDIRIM

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
INDUSTRIAL DESIGN

SEPTEMBER 2014

Approval of the thesis:

**NATURE INSPIRED DESIGN PARADIGMS FOR DESIGN IDEATION: A STUDY ON PACKAGING DESIGN**

submitted by **NUR YILDIRIM** in partial fullfilment of the requirements for the degree of **Master of Science in Industrial Design Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Gülay Hasdoğan
Head of Department, **Industrial Design** _____

Inst. Dr. Hakan Gürsu
Supervisor, **Industrial Design Dept., METU** _____

**Examining Committee Members**

Inst. Dr. Barış Yazıcı
Industrial Design Dept., METU _____

Inst. Dr. Hakan Gürsu
Industrial Design Dept., METU _____

Assist. Prof. Dr. Naz Börekçi
Industrial Design Dept., METU _____

Inst. Mete Ahıska
Industrial Design Dept., METU _____

Assist. Prof. Dr. Ali Emre Berkman
Industrial Design Dept., TOBB ETU _____

**Date:** September 5, 2014

**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

Name, Last name : Nur Yıldırım

Signature :

## ABSTRACT

### NATURE INSPIRED DESIGN PARADIGMS FOR DESIGN IDEATION: A STUDY ON PACKAGING DESIGN

Yıldırım, Nur

M.S., Department of the Industrial Design

Supervisor: Dr. Hakan Gürsu

September 2014, 187 pages

The objects in our daily lives and the natural entities that surround us are embedded with ingenious solutions, each of which is tailored for specific design problems. These essential forms, techniques and properties that originate in nature and human designs have led to an accumulation of strategies through years. There are various tools for the utilisation of these knowledge in design practice; nature inspired design approaches enable using nature's models and principles for sustainable design solutions and paradigmatic approaches help to understand and interpret the essential workings in nature and objects to employ them as principles in problem solving. This study aims to explore the intersection of these two approaches and to investigate the effects of integrating this proposed model into the design process. A card based tool – Nature Design Paradigms Card Deck – was developed and utilised in a workshop exercise focusing on packaging design to analyse the implications of the approach. The conducted research showed that the tool supported the idea generation phase through accelerating and enhancing the process. The thesis discusses the development, implementation and evaluation of the approach with the assessments of design students and the exercise outcomes.



Keywords: nature inspired design, design paradigms, biomimicry, packaging design, idea generation tool

# ÖZ

## TASARIMDA FİKİR GELİŞTİRME İÇİN DOĞADAN İLHAM ALAN TASARIM PARADİGMALARI: AMBALAJ TASARIMI ÜZERİNE BİR ÇALIŞMA

Yıldırım, Nur

Yüksek Lisans, Endüstri Ürünleri Tasarımı Bölümü

Tez Yöneticisi: Dr. Hakan Gürsu

Eylül 2014, 187 sayfa

Günlük hayatlarımızda yer alan objeler ve etrafımızı saran doğal oluşumlar, her biri belirli tasarım problemlerine yönelik özelleşmiş pratik çözümler barındırmakta. Kökenini doğa ve insan tasarımlarından alan bu temel formlar, teknikler ve özellikler yıllar içerisinde stratejilerin birikimine öncülük etti. Bu bilgilerin tasarım pratiğinde kullanımına yönelik çeşitli araçlar mevcut; doğadan esinlenen tasarım yaklaşımları doğa model ve prensiplerinin sürdürülebilir tasarım çözümleri için kullanımı sağlarken, paradigma yaklaşımları doğa ve objelerin özünde yer alan çalışma prensiplerini problem çözmede kullanmak üzere anlamaya ve yorumlamaya yardımcı olmakta. Bu çalışma, bu iki yaklaşımın kesişimini araştırarak, tasarım sürecine dahil edilebilecek bir model önerisinin etkilerini incelemeyi amaçlıyor. Çalışma sürecinde, bu yaklaşımın sonuçlarının analizi için kart tabanlı bir araç – Doğa Tasarım Paradigmaları Kart Destesi – geliştirilmiş ve ambalaj tasarımı odaklı bir çalıştay egzersizinde kullanılmıştır. Yürütülen araştırma, aracın fikir geliştirme aşamasını hızlandırarak ve iyileştirerek desteklediğini göstermiştir. Tez, yaklaşımın geliştirilmesi, uygulanması ve ölçümünü tasarım öğrencilerinin değerlendirmeleri ve egzersiz sonuçları ile tartışmaktadır.

Anahtar kelimeler: doğadan ilham alan tasarım, tasarım paradigmaları, biyomimikri, ambalaj tasarımı, eğitim aracı

## ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor Dr. Hakan Gürsu for his invaluable insights and support throughout this thesis, and also for providing me with his knowledge and experience as a mentor. I am thankful for his encouragement and inspiration that always lead me to outdo myself.

I would like to thank all the students who participated in the field study of this thesis, especially the industrial design students at METU ID.

I also would like to thank the Designnobis team for their support through my absence for writing this thesis.

Finally, I am grateful to my family for their love and believe in me.

## TABLE OF CONTENTS

## LIST OF TABLES

TABLES

## LIST OF FIGURES

FIGURES

# CHAPTER 1

# INTRODUCTION

Humankind, the species that accumulates knowledge and passes it through generations by a variety of media, has developed its own material culture through history. Generated as solutions to a diverse range of design problems, the objects in our daily lives are embedded with ingenious solutions that are influenced by nature profoundly.

As a major inspiration source, nature posed both challenges and opportunities to all the living. Through this struggle, humans observed the nature firstly to understand and overcome the threats, and then to learn from its strategies in creating things. In this sense, nature not only provided the materials to build upon, but also the ways to build. The dimensions of the nature effect within things can be better understood through the invention of the wheel as an example, which is even considered as nature inspired, by the rolling logs.

Collected through years, these essential forms, techniques and properties that originate in nature or manmade objects are curated as a diverse repertoire of archetypal solutions in design. As toolmakers, humans tend to adapt the existing ways of solving problems and nature presents a variety of methods to derive from.

Within this ongoing process, the models and techniques are still being developed with the knowledge acquired through studying nature. From a design perspective, both approaches – observing the nature and utilising the essential design solutions – are practiced as methodologies to support design process. Nature inspired design approaches aim to make use of nature's models and strategies for creating sustainable solutions. On the other hand, paradigmatic approaches aim to understand

and interpret the essential workings in nature and objects in order to employ them as principles in problem solving.

Offered as methods and tools to be used in design area, both approaches present beneficial applications for design practice. Besides their implementations in development of commercial products, the techniques are proven useful for the idea generation process as well. Further exploration is required in terms of the combined use of approaches within the design ideation stage.

### 1.1 Problem Definition

Having focuses of innovation and sustainability, both nature inspired design and design paradigms approaches introduce principles and strategies that can inspire designers in creating efficient and improved products and systems. Though there are methodologies for integrating these approaches into design process, a synthesis through a systematic analysis and experimentation is lacking. The integration of these two models in idea generation within product design process may lead to a more creative ideation phase through associations and analogies. Thus, the approaches can be blended into a catalyser that enhances the process of idea development.

Several aspects are to be considered in utilising these practices in design ideation stage as both methods have their own dynamics. Yet, there are intersections and overlaps between approaches as they both include strategies and solutions for design problems. This interrelated nature holds the potential for an exploration of the concepts within the context of design. In addition, the critical attitude towards the purposes of things can be useful for the perspective shifts in problem solving.

Moreover, an inquiry of the ways designers are influenced with these approaches within their product development processes may be helpful in discovering the underlying problem-solving mechanisms that are employed in design education and practice. As the use of analogies and metaphors in design thinking is a common

method, the dimensions of transfers between concepts - such as forms, mechanisms or material qualities - need further investigation.

### 1.2. Aim and Objectives of the Study

This study aims to explore the implications of nature inspired design and design paradigms approaches for the idea generation stage in industrial design practice. The methods are integrated into the design process through a workshop exercise that makes use of a card based tool for incorporating nature principles and paradigms. The tool – Nature Design Paradigms (NDP) Card Deck – was developed within the context of this thesis to provide a practical method of inspiring from and employing strategies found in nature and manmade objects. The exercise was focused on packaging design, as it is a field that benefited from these interrelated solutions for innovation and sustainability. The exercise was conducted among second year industrial design students at Middle East Technical University (METU) to investigate the utilisation of nature and human problem solving methods in ideation phase.

The research includes the following objectives:

- To examine the nature inspired design approaches, design paradigms approach and the relation between these concepts in terms of design and packaging in particular,

- To explore the utilisation of these approaches in product design process and the integration of both models within an intersecting problem solution methodology,

- To investigate the outcomes of this methodology through an idea generation exercise with a focus of packaging design for the assessment and further improvement of the approach.

## 1.3 Research Questions

The main research question is:

- How can a strategic tool that utilise nature and design paradigms for enhancing and supporting idea generation be developed to inspire the idea generation phase and what would be the implications of the integration of this methodology into the design process?

The secondary research questions are:

- What are the nature inspired design and design paradigms approaches, how do they relate to each other in terms of problem solving strategies and what tools and methods are used to employ these approaches in design process?

- How would the implementation of this approach within the design process affect the designers' perception on nature, design paradigms and their relation with design as problem solving models and strategies?

- What are the considerations and aspects in integrating nature and design paradigms approach as a tool into idea generation phase and how do designers respond to this process in terms of outcomes and evaluations?

- In what ways, i.e. form, structure, materials, could packaging design benefit from these strategies and solutions for more efficient, innovative and sustainable designs?

## 1.4. Structure of the Thesis

This thesis is consisted of five chapters as presented in Figure 1.1:


Figure 1.1 - Structure of the thesis

Chapter 1 provides a brief introduction to the study, presents the problem definition, the aim, objectives and scope of the study and identifies the research questions and the structure of the thesis.

Chapter 2 covers the literature review and the findings. Starting with a background on the subjects of nature, paradigms and design, it examines the origins of these approaches and their relations. The chapter includes a detailed overview of the nature inspired design approaches and their use in design process. It is followed by the exploration of the design paradigms approach and its use as an idea generation method. The literature review continues with the packaging design subject and introduces the key concepts within the field. Finally, the chapter concludes by illustrating an idea generation process example in packaging design and the applications of the approaches to package products.

Chapter 3 presents the methodology and the research stages followed in the study and outlines the used research methods and techniques for data collection and analysis. The chapter explains the development and integration of a card based idea generation tool - Nature Design Paradigms Card Deck - into the design process within a workshop exercise that focuses on packaging design. The steps for the preparation, utilisation and evaluation of the approach are presented in detail within this chapter.

Chapter 4 focuses on the main research and presents the conduct of the preliminary and primary researches and the analysis of their results. The chapter discusses the aspects of the integration and implementation of the approach through a card based tool within a workshop. It continues with the analysis of the participants' assessments of the approach and presents the outcomes of the idea generation exercise to explore the implications of the method. Diverse examples from student cases are examined in this chapter to understand the use of the tool, its advantages and disadvantages. The chapter concludes with the conclusions and insights derived from the research.

Chapter 5 summarises the overall findings and conclusions from the study through revisiting the research questions and suggests key points for further research.

# CHAPTER 2

# LITERATURE REVIEW

As this study is mainly focused on nature inspired design, design paradigms concept and the effects of utilising these approaches in design process – packaging in particular, it was necessary to examine these topics from a critical standpoint and explore the connections between.

This chapter presents the results from the literature review within a general framework on the themes. Following an introduction that provides contextual background, nature inspired design approach is discussed through its origins, terminology and methods in the first section. Subsequently, the design paradigms approach is introduced with its utilisation in design process. In the third section, packaging design, its focuses and considerations are explained along with the nature and paradigms inspired package design examples.

## 2.1. Introduction: Art, Science, Nature and Design

Being one of the major inspiration sources of humans, nature has always attracted the attention of mankind with its alluring qualities. Through his survival struggle in earth, the humankind observed the environment, the flora and fauna to effectively use its resources for both food and protection. Nature, from this perspective, presented many challenges, as it was an unknown realm that has enormous powers to be coped with. Afraid of its disastrous forces, humans tried to make sense of this habitat and gained considerable amount of control over its sources through time.

Across this ongoing journey, the mankind was affected by nature profoundly in the things he built. As Ternaux (2011) stated, the observation of nature and understanding the mechanisms behind the function of organisms have influenced the human creations in a variety of fields including art, architecture, scientific research and industrial innovation. From the development of the tools to the establishing of the object culture and technology, humans referred to nature both as an inspiration and a material source. Even the wheel, which is generally acknowledged as one of the most significant human inventions, is asserted as a nature inspired object that could be influenced by rolling logs. Either way, the human technologies and the history of inventions have a great number of nature-influenced examples.

Nature represents a field of research that is at the intersection of humanities and natural sciences and contrasting approaches exist in the study nature in terms of 'wonder' with religious influence and 'curiosity' of Renaissance, which is the basis of scientific thought (Ball, 2013). Science examined the nature and the universe to discover the secrets they hold, thus nature became a school, whereas systematic methods were developed for observing and adapting the ways nature works.

Design, on the other hand, is considered as a tool for making tools, for the humans are toolmakers. As Ternaux indicates, design constitutes a crossroads between creativity, the arts, sciences and technologies, thus is the interface between these contexts for innovation (Ternaux, 2011). Since nature inspired the human creations of all kinds, it influenced the ways of creating as well. In this sense, the similarities between nature and design are visible in the way that both provide answers to specific purposes.

Stating that nature is a wealthy source in terms of design solutions, Wake (2000) points to the paradigmatic quality of the strategies that plants and animals employ. In his words:

> Many of these [design solutions] are paradigmatic; such as the layers of an onion or the way a kangaroo carries its young in a pouch. …A ball shape, for instance, will tend to roll.

Referring to the design paradigms as a framework that explains the workings of natural and designed objects, Wake emphasises the shared principles in nature and design as essential solutions (Wake, 2000). Likewise nature designs, manmade designs are apt to evolution through time in accordance with the laws of nature.

Today, nature designs are perceived as systems that achieve perfect economies of energy and materials and nature's principles such as sustainability, optimisation over maximisation, closed cycles instead of linear processes are favoured in several disciplines related to science, technology and design (Gelli, 2011). In other words, through a battle to rule its powers and resources, the humankind has come to terms with nature as the environmental concerns made it a survival necessity. With the consciousness of the fact that the existing sources are limited and being depleted rapidly within the global mass production and consumption, the current industrial system is being questioned to achieve more sustainable means of living.

Victor Papanek envisioned in his pioneering book 'Design For the Real World' that a biomorphic era is emerging over the mechanical and technological eras of the last centuries and it will enable a shift from static and dynamic technologies to evolving parts (Papanek, 1984). Nearly thirty years later from his prediction, the utilisation of biological knowledge in the design of products and technologies is still being increased, as well with the research in area of nature methods and principals for sustainable products, systems and processes. Several approaches are being developed in the area of employing nature's solutions. The next section delivers a background on nature influence in human works and presents an overview of the nature inspired applications.

### 2.2. Nature Inspired Design

As mentioned earlier, the influence of nature on manmade things can be observed throughout the history of arts and sciences. Humans explored and examined their environments and imitated its laws with both aesthetical and structural concerns. The discovery of Fibonacci sequence and the golden proportion as the mathematics of function and beauty inspired the Greek and Roman arts, architecture and

sculpture. One of the best known nature inspired designers was Leonardo da Vinci, who studied the basic geometries in natural forms including the human body, animals, plants and insects. Da Vinci pointed nature's qualities of beauty, simplicity and well-adaptivity and stated that 'nothing is missing and nothing is unnecessary' in its inventions (da Vinci, 1883/1970). This optimisation in natural systems still attracts scientists and designers from various disciplines. In terms of design, on the other hand, nature was acknowledged as a system that achieves 'the most with the least' and therefore was referred to as a handbook of optimal solutions for man's problems (Papanek, 1984).

The nature influenced design practices illustrate several approaches to the subject. The comprehensive examination of these significant works that led to the emergence of the term 'nature inspired design' shows the ways nature was interpreted by creators. Providing an overview on the subject, Carlos Montana Hoyos (2010) presents a timeline of designs that were inspired by nature from the industrial revolution to the current date through key points and examples (Figure 2.1).

As can be seen from Figure 2.1, Hoyos evaluates the theme within three focuses, namely form, function and systems. Regarding the form driven approaches, stylistic movements such as Art Nouveau and Art Deco are listed alongside the more efficiency-oriented approaches like organic design. Represented by famous designers such as Luigi Colani and Eames couple, this methodology is worth mentioning as it investigates the ergonomic efficiency and optimisation of forms through a curvilinear architecture (Ternaux, 2011). As time moved forward, the focus of the approach shifted from the natural-looking appearance in products to the forms that associated efficiency and environmental integration with the use of materials and energy.

A second approach exists with a focus of technology and is illustrated with examples from human inventions that span from the glider of Wright Brothers to the robots mimicking the living organisms. As the scientists and designers observed nature from an evolutionary perspective, they were intrigued by the correlation between form and function.

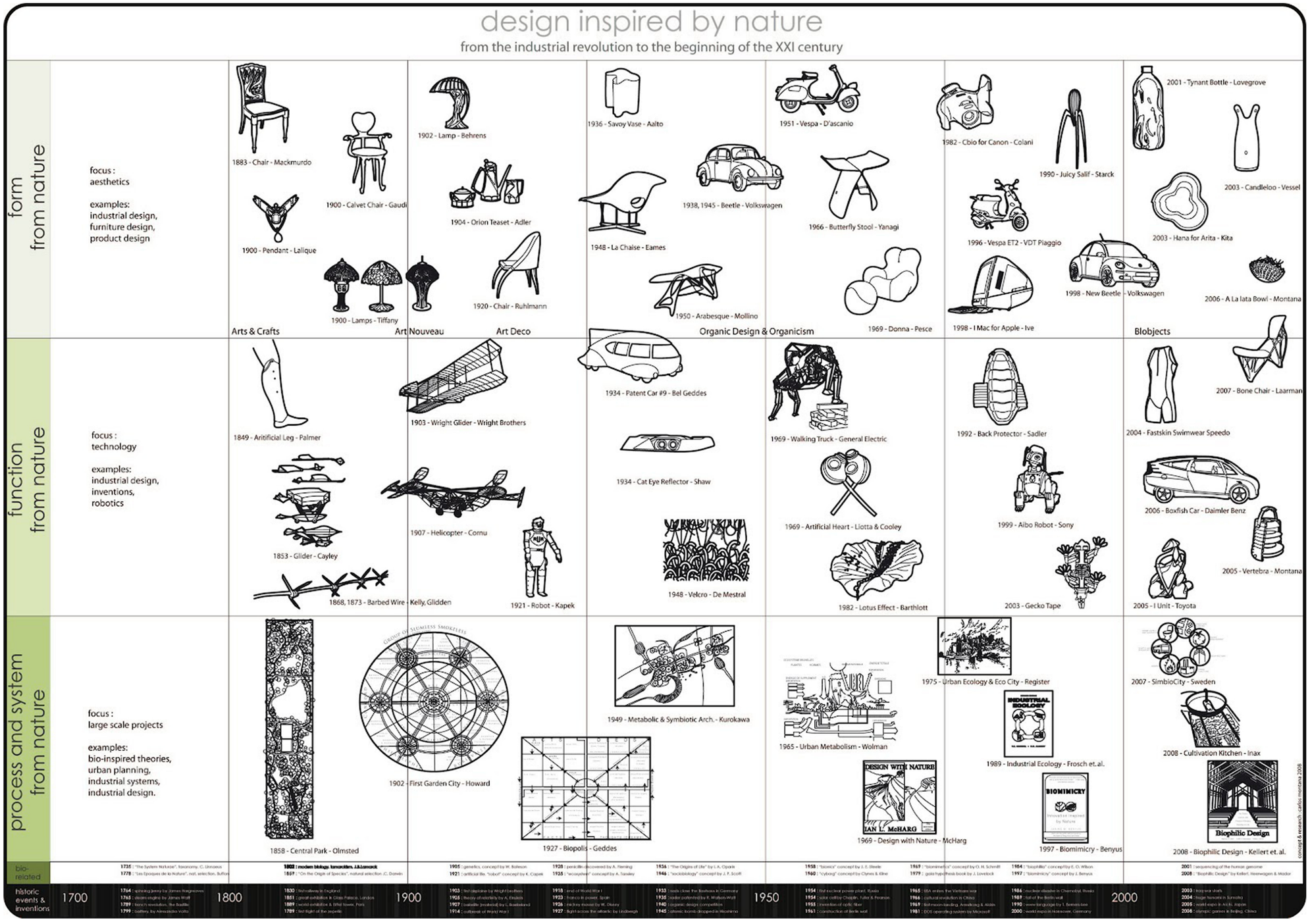



Figure 2.1 – Timeline of Design Inspired by Nature (adapted from Hoyos (2010), retrieved from: http://bioinspired.sinet.ca/files/bioinspired/users/nhoeller/biomimicry%26designA4WEB.jpg

The matching of specific functions to forms that are adapted to enable these purposes in an intrinsic way led the researchers from several disciplines to question the laws governing this situation. This functionalism in nature that is achieved through an evolutionary accumulation has influenced the design field and constituted a major concept, especially within the architecture area (Ternaux, 2011). The famous dictum by 19th century architect and industrial designer Louis Sullivan summarises the main thought of this principle by suggesting that the elements of a design should stem from its function. Embraced by distinguished designers such as Frank Lloyd Wright, Alvar Aalto and Mies van der Rohe, the functionalist approach holds similar concerns to organic design as it focuses on efficiency and optimisation through the expression of structure and use of natural materials (Myers, 2012).

As a third level, process and system inspired approach is defined, which includes the study of biological ecosystems on both macro and micro scales. Patterns and relationships found within the organisms prompted the bio-inspired theories. The Central Park and Biopolis Project are among the examples of nature-influenced designs within the urban planning field. In addition, the systematic study of nature led to the emergence of disciplines that focus on applying the nature's methods and principles in manmade processes. Several approaches were developed with a similar aim under different names, such as Bionics, Biomimetics, Biomimicry etc.

To conclude, various interpretations of the nature theme can be found through the history of design. As for today, nature is described as a source of sustainable and effective solutions that can be referred to achieve innovation in manmade systems and designs. The terminology regarding the subject will be discussed in the next section.

### 2.2.1. Nature Inspired Design Approaches

Nature related or 'bio' design approaches could be generally defined as the processes of making use of nature in order to derive from its sources and strategies for the creation of products. A variety of methods with subtle differences are present

in the literature. An outline of these terms along with their focuses is presented in Table 2.1.

Table 2.1 – Nature Inspired Design Approaches (adapted from Ternaux, 2011)

| |
|---|
| **Bio-utilisation:** The use of parts of organisms as raw materials, such as building a house from wood. |
| **Bio-assisted technologies (also referred to as Biotechnology):** Utilising living organisms or biological processes to acquire or manufacture products, like using bacteria to clean wastewater or simply domesticating a cow to produce milk. |
| **Biomimicry (also known as Biomimetics, Biomimesis or biogenesis):** The study and emulation of nature's methods and strategies to solve design problems within various fields including functions, processes, materials and energy. |
| **Bionics**: The early uses of the term refer to studying and applying biological systems to design problems, similar to newly emerged Biomimicry approach. Today, bionics is described as the study of natural mechanisms, especially of living organisms, to apply them in different technological domains – e.g. robotics – and engineering in particular. |

In brief, there are three kinds of bio approaches: bio-utilisation as the process of harvesting the product, bio-assisted technologies as the process of breeding the producer, and bio-mimicking as the process of becoming the producer (Benyus, 2011, p. 40). For the main area of this research, Biomimicry discipline constituted a prominent resource as it offers various methodologies on the integration of the nature strategies to design practice.

Utilisation of nature's principals offers several benefits and opportunities in diverse fields within particular focuses of innovation and sustainability (DTI Global Watch Mission, 2007). Improving the overall design through efficiency and physical properties, nature inspiration enables developments in engineering, design, chemistry, computing, haptics, material sciences, mechanisms, social interactions

etc. In terms of product design, on the other hand, the approach may help to achieve effectiveness in structure, form, function, materials, energy, system and process.

In terms of sustainability, nature has an intrinsic quality of continuity where everything is part of a system, therefore connected and transformed yet nothing is wasted (Gelli, 2011). Regarding the nature inspired design practice, it was stated that the approach does not have to aim for achieving sustainability in the first place. Nonetheless, Benyus indicates that mimicking nature may yield sustainable solutions as the strategies of life and organisms have an inherent goal of optimisation (Benyus, 2011).

As this study aims to develop a practical approach for utilising nature inspiration in design process, nature inspired design literature along with the existing methods and tools were examined in detail. It was seen that although their names differ, the processes offered for product design are quite similar in different contexts such as in design or engineering. This study has mostly benefited from the biomimicry approach, which is comparatively more appropriate for industrial design practice with the methodologies it introduces. The next section elaborates on this discipline and the methods and tools it provides for product design.

#### 2.2.1.1. Biomimicry

Deriving its roots from Latin words bio meaning ‘life’ and mimesis ‘to imitate’, Biomimicry is described as a way of observing and taking inspiration from nature in order to create (Ternaux, 2011). The emergence of the term is attributed to Janine Benyus, who popularised the approach with her book titled ‘Biomimicry: Innovation Inspired by Nature’. According Benyus, biomimicry is the process of learning from and emulating nature’s designs, recipes and system-wide strategies for creating life enhancing designs (Benyus, 1997).

Defined as an interdisciplinary approach that connects nature and technology, biology and innovation, life and design, biomimicry introduces systematised ways of learning from natural world and seeking solutions to design problems with principles

in nature. Through a non-profit organisation called the Biomimicry 3.8 Institute, the discipline presents tools, guidelines and frameworks to apply these principles within the design process. Benyus indicates that there are three levels in the application of biomimicry to product design as form, process and ecosystems levels. The approaches are referred to progress from shallow towards deep whereas a distinction is made as 'reductive' and 'holistic' between views (Benyus, n.d.).

The first level is defined as the mimicking of natural form; shapes, surfaces, textures and pointed out as the beginning in process, which may not necessarily lead to sustainable solutions. A biomimic-aspiring designer from IDEO, Robert Suarez, refers to the bullet train example in his slide that explains the range of applications of biomimicry to diverse design challenges (Figure 2.2).

As the figure illustrates, the Shinkansen bullet train was inspired by the Kingfisher bird that goes from air through water without a splash with its aerodynamic beak. Using this strategy, the Japanese high-speed train achieved a reduction in air resistance and noise through tunnels and succeeded as a faster and more efficient train (Suarez, 2012).

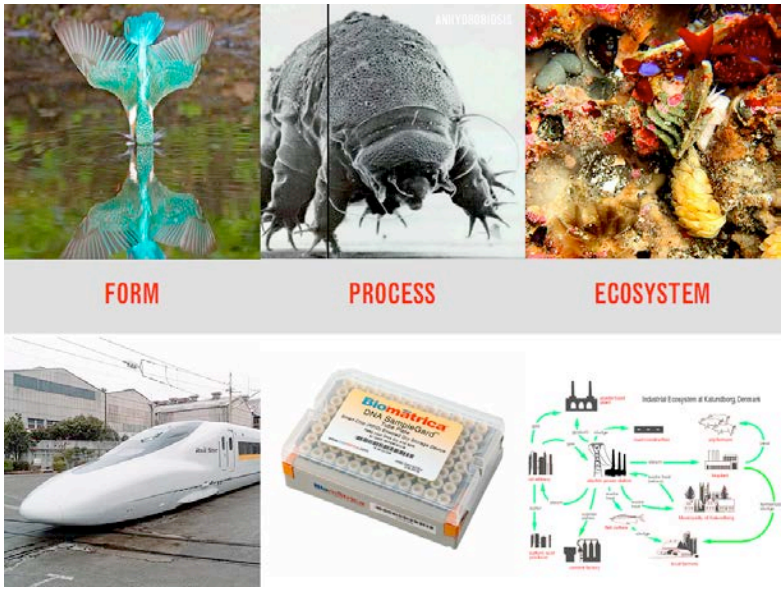



Figure 2.2 – Biomimicry Levels: Form, Process and Ecosystem by Robert Suarez (retrieved from: http://31.media.tumblr.com/tumblr_lzqaczc8Kq1qgn2jro1_1280.jpg)

The second level includes the mimicking of natural process as a series of operations and inquires how things in nature were made. Within this deeper level, strategies from nature are explored through the ingredients and reactions that make these processes possible. Figure gives the example of Biomatrica dry storage device that mimicked the Water Bear insect's process of drying and coming back to life fully functioning with only a drop of water, in order to preserve human DNA and similar samples.

In the third level, natural ecosystems are mimicked to inspire the manmade systems as models for a sustainable larger economy where each product fits within a closed lifecycle. Kalundborg Symbiosis is an example of imitation in ecosystems level, which constitutes the world's first industrial symbiosis as an eco-park. Inspired by the mutualistic relationship between organisms, the system is designed in accordance with this principle and has a waste cycle as well.

In terms of their utilisation, the reductive approach is considered as the imitation or transfer of a few features or functions of particular organisms or biological processes to design field (Reap, Baumeister & Bras, 2005), whereas the holistic view is employed as a measure to achieve sustainable products, systems and processes in terms of their production, use and disposal (Volstad & Boks, 2012). Within the field study of this thesis, the levels of inspiring from nature were conveyed with examples through a presentation and the outcomes were analysed to assess the results. The details regarding this issue will be provided in the upcoming chapters.

### 2.2.2. Methods and Tools

Various tools are developed for the integration of Biomimicry approach into the design process and accessible as online handbooks or resources within the Biomimicry 3.8 Institute. The guidelines are offered in various forms; methods or processes, frameworks of principles, case studies, examples from nature strategies and online databases are available as assets. An overview of these tools is presented in this section.

**Biomimicry Thinking: Design Spiral Approaches**

Biomimicry Thinking is a framework that intends to relate nature inspiration into the design process of any discipline at any scale (Biomimicry.net, n.d.). Referred to as design spirals as well, the guideline presents two main methods for the application of the Biomimicry approach: 'challenge to biology' and 'biology to design'.

The first approach 'Challenge to Biology', or the 'top-down' process, originates in an identified design problem and explores nature insights for solutions to that challenge (Macnab, 2012) (Figure 2.3). An example of this approach is the boxfish inspired car, where designers looked for an aerodynamic yet structurally whole form that can be compatible for a car concept and arrived at the Boxfish as a streamlined solution with low resistance. Beginning with the question 'How does nature do that?', this path is described useful for controlled settings such as an iterative design process or a classroom.

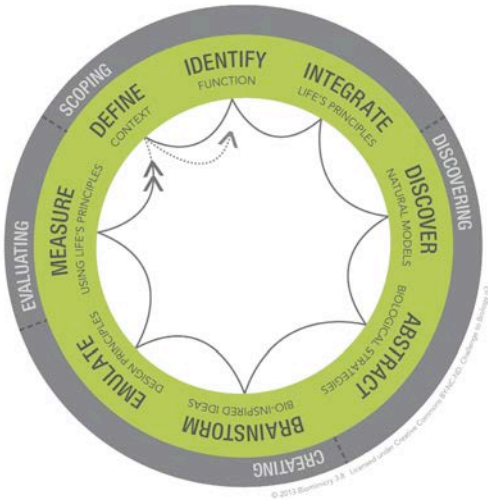



Figure 2.3 – Challenge to Biology (retrieved on June 1, 2014, from: http://biomimicry.net/about/biomimicry/biomimicry-designlens/biomimicry-thinking/)

The second approach 'Biology to Design' – also known as the 'bottom-up' process – represents the process of starting out with nature observation and proceeding towards the design solution through the emulation of nature strategies (Figure 2.4).

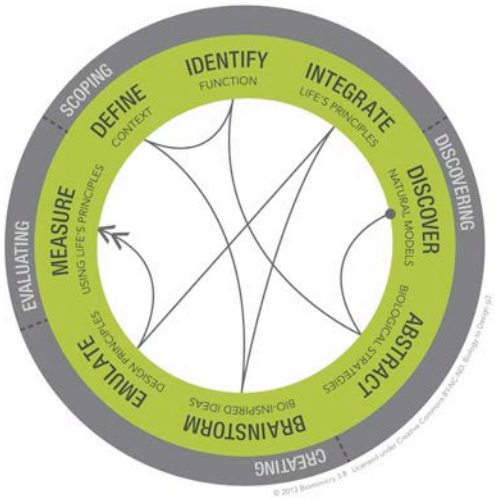



Figure 2.4 – Biology to Design (retrieved on June 1, 2014, from: http://biomimicry.net/about/biomimicry/biomimicry-designlens/biomimicry-thinking/)

The invention of Velcro fasteners is an example of this approach, as the examination of burrs stuck to a dog led to the discovery of tiny hooks that is able to catch any cloth or fur (Hiskey, 2012). Thus, the two-part fastener system was developed as a design solution for joining. This path was found appropriate when the design process is initiated by nature insight and strategies that may turn into new innovations.

Biomimicry Thinking framework is helpful in establishing the four essential steps in design process, as they are present in both circles as well: scoping, discovering, creating and evaluating. In terms of the followed methodology, 'Challenge to Biology' approach was found convenient for the field study exercise of this research, as it included a design process with a specific design brief.

### The Biomimicry Taxonomy

Introduced as a functional organisation of biology, the Biomimicry Taxonomy is a tool that classifies natural systems and organism according to the strategies they adapted for challenges (AskNature.org, n.d.). In other words, the framework enables to find potential solutions through representing how nature achieves a specific purpose in response to particular problems.

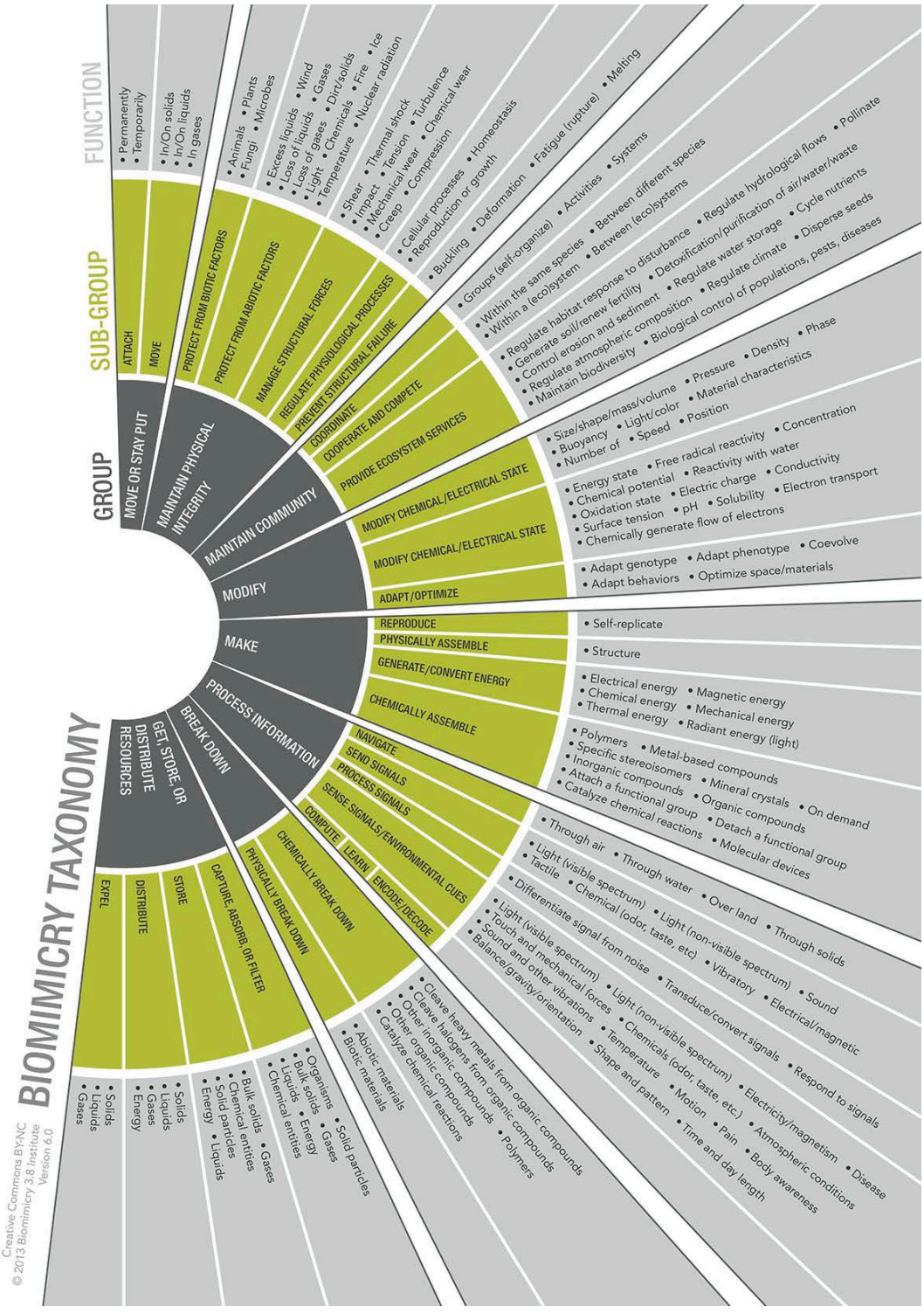



Figure 2.5 – Biomimicry Taxonomy by the Biomimicry Institute (retrieved on June 1, 2014 from: http://static.biomimicry.org/asknature/biomimicry_taxonomy-v6.0.pdf)

Developed by the Biomimicry 3.8 Institute, the Biomimicry Taxonomy is presented in Figure 2.5. As can be seen, the strategies are categorised into groups and sub-groups that are followed by various functions within different fields. The tool is referred to within this study through the development process of the card deck tool and found helpful in specifying the paradigms and principles to be used (see section 3.3.1.2.1). Using this guide, it is possible to refer to examples from nature and organisms via the online database AskNature.org. The next section discusses the online sources and their use in the process.

**Online Databases: AskNature.org**

The databases that illustrate examples of biological strategies constitute an important source for nature inspiration in design process. As the observation of natural organisms and systems is limited to the place and the biology knowledge, a library of existing solutions is useful in the discovery of nature paradigms.

Initiated by the Biomimicry Institute, AskNature.org is an online database that catalogues hundreds of strategies for an easy reference. Within the index, nature solutions are presented along with related information on the organism, the challenge and the strategy linked with Biomimicry Taxonomy, functions, possible applications in industry and similar examples. In addition, case studies are provided for the exploration of the products stories with nature inspiration.

**Biomimicry Sketch Analysis**

A tool for learning and inspiring from nature to translate its strategies into design ideas within the context of a design project was developed in the Department of Industrial Design at METU. The exercise, namely the Biomimicry Sketch Analysis, consists of three stages as observation, analysis and transfer and encourages designers to perform these tasks through various media, sketching and photographing in particular. Aiming to integrate the biomimicry approach into the product design education for sustainability, the method is developed as an analysis and solution-oriented tool for the idea generation process (Bakırlıoğlu, 2012).

### Biomimicry Workshops

The nature inspired design approach, the biomimicry principles in particular, is implemented within the idea generation process in form of workshops. The interdisciplinary exercises utilise nature's knowledge for more sustainable design practices through the introduction of approach, observation of nature with walks and databases and ideation on the natural inspirations (Kwon & Fraiser-Scott, 2012). The workshops span from one-day intense exercises to a week long programs that are tailored according to the participant profile and needs.

Within the context of this thesis, a hands-on tool in form of method cards, called Nature Design Paradigms (NDP) Card Deck was developed to inspire from nature and paradigms through the design process and to transfer solutions and strategies to design challenges in idea generation stage. The NDP Card Deck tool will be introduced and explained in detail in the upcoming chapters.

## 2.3. Design Paradigms

Meaning ‘a typical example, pattern’ or ‘an outstandingly clear archetype’, the word paradigm is used to describe distinct models or concepts (Paradigm, n.d.). The phrase ‘design paradigms’ on the other hand, is mentioned in various literatures regarding design, architecture and engineering. Also referred to as ‘principles’, ‘strategies’ or ‘purposes’, the term relates to the archetypal design solutions or approaches in problem solving.

A common example used in explaining the term is the Swiss army knife that illustrates the concept of a single object with multiple functions for different purposes. As the paradigms are frameworks for explaining the principles behind objects and things, the concept easily conveys it’s meaning to the receiver. Warren Wake, who presents a glossary of distinct forms, mechanisms, techniques and relationships that represent fundamental design strategies in his book ‘Design Paradigms: A Sourcebook for Creative Visualisation’, explains the phrase as ‘a term that we use to talk about a thousand different great little ideas that are at the heart of

natural and manufactured devices' (Wake, 2000). Emphasising their quintessential quality, Wake suggests that similar to atoms, design paradigms constitute the basic building blocks of design. The characteristics, patterns and use of design paradigms are explained in the next section.

### 2.3.1. Recognising and the Uses of Design Paradigms

Characteristically, design paradigms are distinctive and comprehensive. Paradigms are encountered in both natural structures and manmade designs as they utilise these essential components as solutions. Van der Ryn states that these basic patterns with particular functions express the dynamic organisation within things at different scales and the recognition of these archetypal patterns is necessary to understand how and why things function and connect (2005).

In this sense, design paradigms allow the exploration of basic forms, functional relationships and behaviours. As Wake indicates, paradigms are easy to recognise and relate to, even in the newly introduced concepts. In his words (Wake, 2000, p.2):

> 'When we first see a set of Russian nesting dolls, for instance, we quickly grasp the concept of object-within-similar-object. After seeing the second doll within the first, and the third within the second, we eagerly look for a fourth and fifth. Further, as we discover a set of nesting screwdrivers or slice open an onion to find effectively another onion inside another, we find that there are many things we might classify as nesting like a set of Russian dolls.'

To illustrate how these paradigms are embedded within objects in our daily lives, a simple parka can be explored as an example (Figure 2.6). Utilising various paradigms for fastening, the subtle arrangement of principles in a parka can be seen, and it is difficult to have improvement by swapping them, yet is easy to achieve a poor combination (Weber, 1993).

Expressing that the paradigms are used in classifying problems and finding parallels in alternate solutions, Wake (2000) points to the similarity of paradigms to metaphors, and states that paradigms act as visual and functional analogies that enable to understand, explain and generate physical objects, mechanisms and art. Like metaphors, which play a key role in learning, paradigms illustrate the way things operate, change and relate to other things. Thus, it was expressed that through analogies it becomes possible to build new and unfamiliar elements (Wake, 2000).

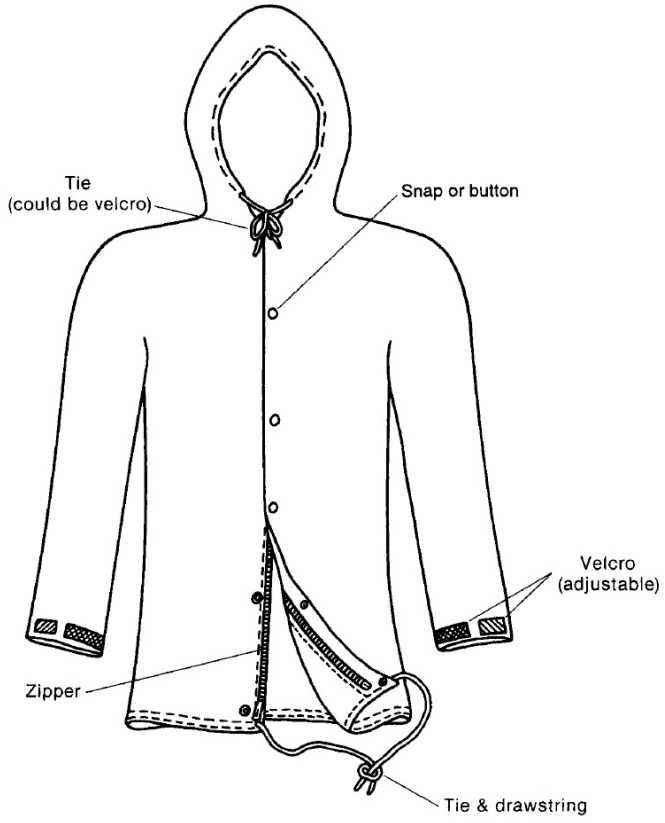



Figure 2.6 – Fastening Principles in a Parka (reproduced from Weber, 1993)

Through learning, observing and designing within their design processes, designers develop individual libraries of design paradigms. As Wake suggests, these fundamental strategies help to build a visual and conceptual vocabulary and create a mental toolbox to draw upon when designing (Wake, 2000). Useful in both learning and problem solving, paradigms take an important part in improving design skills.

Regarding the design process, the use of paradigms and metaphors is widely recommended as a method in idea generation for design (Lockton, 2014). Saffer (2005, p.6) emphasise the role of metaphors in interdisciplinary mapping for designers by stating that metaphors enable to conceive new subjects through known concepts and allow reshaping the familiar objects and experiences into abstract items. The method is also suggested as a way to trigger new perspectives on a problem (Seelig, 2009). There are a number of tools and methods that are developed to integrate the paradigms approach into the design process to increase creativity in idea generation phase, such as Six Thinking Hats (de Bono, 1990), Synectics (Gordon, 1961), TRIZ (Altshuller, 1994) etc. In this study, on the other hand, a selection of paradigms is formed into a card deck to be utilised in the design ideation stage.

The next section examines the design model for employing the design paradigms in idea development process, which will be referred to in the proposed integration of the developed card deck tool into the design process.

#### 2.3.1.1. The Utilisation of Design Paradigms in Design Process

As an approach to problem solving, design paradigms method is employed to foster metaphorical thinking for a creative design process. Similar to product design process, the use of paradigms approach in design process follows iterative steps from problem framing to synthesising and solution finding.

In his book 'Design Paradigms', Wake (2000) introduces a basic methodology to utilise paradigms approach in design process consisting of four main steps: reduction, selection, application and test (Figure 2.7). Starting with the deconstruction of the challenge or existing solution, structure of the problem is analysed through paradigms in the reduction phase. In addition, objectives are specified to search for directions for improvement. Following this phase, applicable paradigms are examined and identified to achieve aims set. In the selection stage, paradigms are explored and evaluated through multiple alternatives. This step is followed by the application phase, in which chosen paradigms are incorporated in

ideation and concept generation. In this step, the integration of paradigms is performed on occasion through combining more than one paradigm when necessary. Finally, the process includes the test phase to verify the idea according to design goals and considerations.

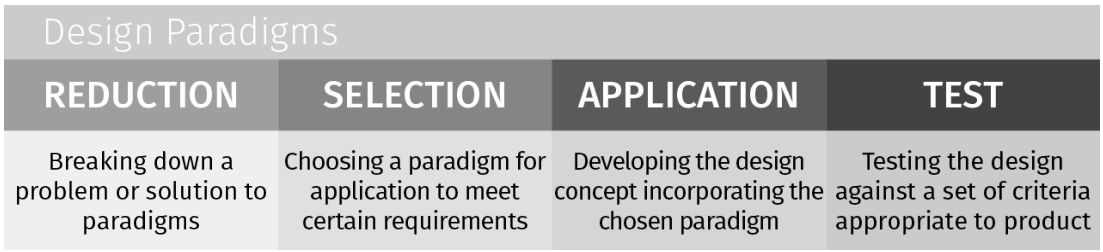



Figure 2.7 – Utilisation of Design Paradigms in Design Process
(adapted from Wake, 2000)

Indicating the cross utilisation of paradigm alternatives between different strategies, functional relationships and behaviours, Wake (2000) mentions an additional level of use as 'paradigm shifts'. Enabling significant changes, the shift occurs when the underlying paradigm is replaced with a dramatically different one that redefines the problem and/or product. The move in photography from the film-based to digital process is a good example of a paradigm shift.

Shifting the paradigm allows to produce revolutionary design solutions and unlike the interpretation of existing designs through using alternate paradigms, it may lead to fundamental shifts. To describe the paradigm shifts in design process, an example of a shoelace problem can be explored. When the difficulty of tying shoelaces was defined as the design problem, an easy to tie shoelace could be designed as a solution. However, through redefining the problem, the scope of the design challenge changes as well as the solutions differ with established goals. If the problem was identified as 'a fastener that is easy to open and close', more progressive alternatives could have been proposed, such as Velcro fasteners. On the other hand, the specification of the context could be reduced to 'an easy to wear shoe', which might lead to even more radical approaches as the elastic shoes that eliminate opening and closing.

As the example illustrates, the design problems can be solved within various levels through paradigms shifts. Thus, the reframing of the problem space with a critical approach in the design process is a technique that helps to employ design paradigms in a more effective way and should be emphasised for the development of solutions with progressive shifts.

### 2.3.2. Design Paradigms in Nature

Nature inspired design and design paradigms concepts have common points in terms of the critical reasoning and the analogical transfer possibilities. Concerning the relationship between problems and their solutions, design paradigms provide insights into the reasons things take particular forms in accordance with their function. Stating that the designs of these mechanisms and organisms mostly originate in nature, Wake indicates the evolution of the paradigms through both natural and human processes (Wake, 2000). This search for the correspondence in challenges and meeting strategies is a shared approach in both methods.

As for the cross-pollination feature, both areas empower the application of working solutions in different fields. ‘Idea creation by analogical transfer’ (Stacey et al 2009, p.362; Tseng et al 2008) is a suggested way in design process and stated as a method that ‘enables mentally to stand back from the specifics of the accumulated examples and form more abstract conceptualisations pertinent to their domain of expertise’ (Cross, 2004, p.432).

These associations create opportunities in the combined use of the approaches within the design process. This thesis aims to explore the utilisation of both principles – nature inspired design and design paradigms – in design ideation with a focus of packaging in order to understand the implications of the approach. The next section presents a proposal for the integration of this method into the idea generation process.

## 2.4. Packaging Design

### 2.4.1. Introduction

Derived from the Dutch originated word ‘baggage’, ‘package’ as noun refers to an object or group of objects bundled together, and verb ‘to pack’ is defined as ‘making into a package’ (Capsule, 2008). In this sense, a simple bindle can be thought of an early example of packaging (Figure 2.8).

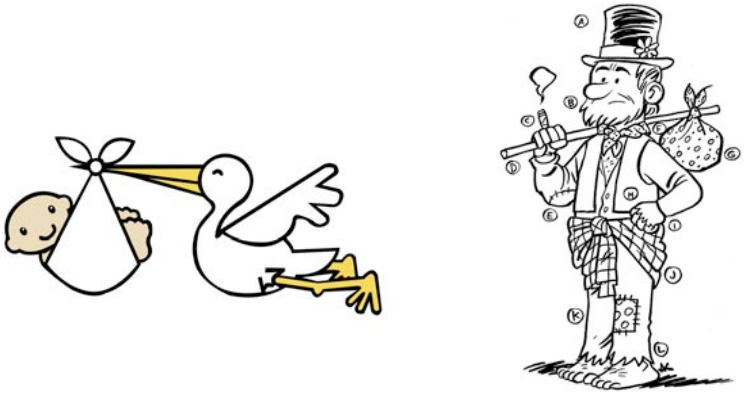


Figure 2.8 – Bindles as packages (retrieved and adapted from: http://clipartbest.com)

As a general concept, packaging can be described as an organisation of items within a three-dimensional space. Evaluated within the widest perspective, numerous things can be referred to as packages, including buildings, vehicles and even the human body, which contains items that relate to each other in a meaningful way (Figure 2.9).

The need for packaging has aroused with transporting, storing, protecting and measuring purposes in general: packing goods for moving or delivery, packing food for keeping, packing items for preserving and portioning. The early packages were mainly containers; baskets, skin bottles, pottery and barrels are examples of the commonly used storage and transportation tools before the industrial era.

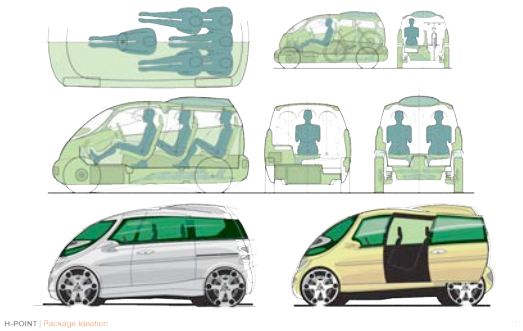


Figure 2.9 – Packaging in Transportation Design in terms of the arrangement of interior and structural components (reproduced from Macey, 2009)

Consumer packaging, on the other hand, dates back to first millennium where vegetables and spices were paper-wrapped in markets (Twede, 2005). Packaging and labelling on an industrial level was shaped around 19th century with the advancements in production and product transfer methods. Essentially, the package was a means of delivery for the products.

Today, as one of the largest mass-produced consumer goods, packages act as interfaces between products and consumers. As stated, packaging is ubiquitous; everything is packed and even the label on an apple is a form of packaging (Capsule, 2008). Used extensively in food and beverages, packaging exists in almost any retail item at any sector: books, CDs, electronics, toys, clothes, various tools and utensils etc.

That being the case, rather then being a mere casing to transport and protect the product, the packaging is now a part of the product or is the product itself (DTI Global Watch Mission, 2007).

### The Human Model of Packaging

Packaging design involves multiple elements to consider in design process like any other category of products. In order to understand these factors, it is essential to explore the characteristics that make a package well designed. In addition to the general design principals, context and human behaviour are vital in designing

packages, as well as marketing, production, branding and legislation. Regarded as one of the leading packaging designers in the world, Lars Wallentin defines good packaging as follows:

> '(Innovative packaging)… has to look good. It's all about aesthetics. It's about creativity: it has to be different. It's about ecology: what do you do with the package afterwards. It's about ergonomics: you need to be able to handle it properly. It's about the five senses ... And packaging has a lot to do with communication: the consumer has to understand instantly what the product is about.' (Wallentin, 2013, p.11)

As mentioned, various qualities are incorporated within a package; along with duties to protect, cover, identify and carry, packaging has an objective of meeting consumer expectations. A package should be easy to use, convenient and attractive and from manufacturing perspective, it needs to be economic and ecologic with its material use and life cycle. All in all, multiple concepts from diverse points of views are associated with the term. The criteria include the design, functions, use, communication and responsibility. Two major focuses are notable as leading ones to shape the future of packaging among these concerns: innovation and sustainability. The next section discusses these aspects in detail.

### 2.4.2. Focuses in Packaging Design

This section explores the contemporary focuses within packaging design including innovation and sustainability.

#### 2.4.2.1. Sustainable Packaging Design Approaches

Abundant packaging has an enormous impact on our environment and it is among designer's responsibilities to think about this problem. Regarding the ecological aspect, packaging are mostly made out of recyclable materials. The packages are collected for recycling, however this is valid for a limited amount. In order to extend

the life cycle of the packaging after its disposal, some major approaches were developed with sustainability concerns:

- Packaging with a second life that is converted to another product in its post use
- Packaging that is designed to be utilised as a part of the product
- Packaging that decomposes through its use
- Packaging that is used multiple times within a cycle, such as deposited packages

Categorisation of the existing practices under these main titles enable a practical overview of the sustainable application in the packaging area, which are explained through examples as follows.

The classic movie 'Gods Must Be Crazy' tells the story of a local tribe in a rural village, whose members find several practical uses to a newly introduced empty coke bottle such as making music, printing, or grinding foods. Although it was parodied, the utilisation of packaging for a variety of purposes after its use is a widely accepted approach in product design and is referred to as the 'post-use' of products. Either intentionally or not, the packages may obtain other uses after being disposed. The conversion of PET bottle to footwear in developing countries exemplifies the unexpected uses derived from the needs rather than sustainability concerns. As the idiom suggests, one man's trash may literally become another man's treasure.

From the designer's perspective, designing with regard to a product's lifecycle and the process of reusing, reducing and recycling – 3R's – opened up new dimensions: rethinking is considered as a fourth level that designers are responsible of. As these approaches highlight, the packages have the largest percentage in landfilled waste, yet have the potential of becoming new products instead of being thrown out.


Figure 2.10 – Cans'n Caps by Dr. Hakan Gürsu aims to revive aluminium beverage cans as functional and fun objects in everyday life (retrieved from: http://designnobis.com)

Pointing out this challenge in his TEDTalk, Dr. Gürsu states that 'food decays while packaging remains sound' (Gürsu, 2012) and suggests a fifth R for the 'Revival' by proposing projects that use packaging waste in a systematised way to achieve new products (Figure 2.10).

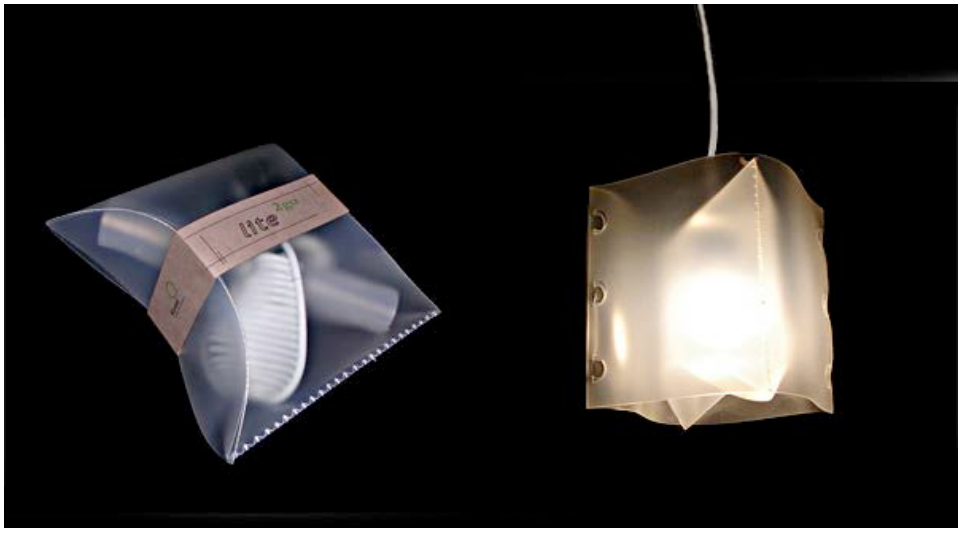


Figure 2.11 – Lite2Go Lighting Design by Knoend (retrieved from: http://images.businessweek.com/ss/08/12/1203_packaging/image/9_lite2go-copy.jpg)

Another utilitarian approach is followed as well, where the package serves as a functional part within the assembled product. The example in Figure 2.11 shows a lighting packaging, in which the package is utilised as a functional and structural element of the design. In this method, the lifecycle of the package is considered in the design process to achieve a product with zero packaging waste. Edible or soluble packaging is an alternative strategy in minimising waste where achievable. Soap packaging design by IDEO (Figure 2.12) uses this solution via embedding herb seeds into molded pack, which decomposes in soil after being planted.


Figure 2.12 – Pangea Organics Packaging by IDEO (retrieved from: http://ideo.com)

Thus, shifting the paradigm instead of replacing it with another, leads to more unconventional ways of dealing with packaging waste and in certain cases, it is nearly possible to completely eliminate the packaging. As an approach that multiplies the uses of the package to elongate the product life span, the deposit system is an old yet still eligible concept. In this case, the material qualities of the package are significant to allow for product longevity.

Aside from making the packages with deposits, it is possible to deliver the products without packaging. Unpackaged grocery store in London is an example that reflects this approach by delivering products through custom refill containers brought by

consumers (Figure 2.13). Though it might be conceived as a radical approach, the idea actually resonates with early retail environments and general stores before the consumption-driven society, where packaging was only a delivery device to stores and many products were packaged in bulk (Capsule, 2008). The concept still exists in old markets and bazaars within the local regions of Europe and Asia.

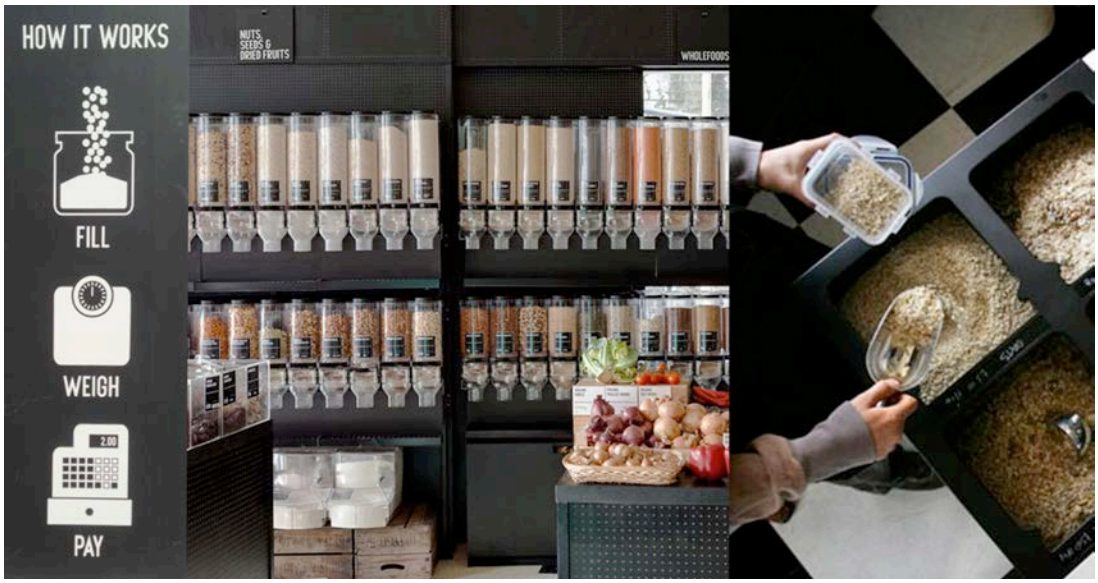



Figure 2.13 – Unpackaged Grocery Store (retrieved and adapted from: http://beunpackaged.com/)

To conclude, there are numerous approaches and methods in designing for sustainability within the packaging products. As the examples illustrate, environmentally conscious approaches in packaging may lead to a design-driven behaviour change in the consumption patterns by raising awareness on the potential of the package. The concerns of sustainability could be incorporated into the exercises that employ nature and design paradigms approach to achieve ideas that aim to solve the environmental drawbacks of packages. Although it is not among the focuses of this research, the issue raises essential questions and should be regarded as a space for improvement in the area.

### 2.4.2.2. Innovation in Packaging Design

From small incremental improvements to paradigm shifting changes, innovation in packaging design is aimed within multiple levels. There are several opportunities that exist to create an innovative package: the context of use, material selection, production process etc. This section provides a brief overview of these aspects, which may benefit packaging design via breakthrough products.

Figure 2.14 – Non-stick Ketchup Bottle by MIT (retrieved and adapted from: http://static.ddmcdn.com/gif/blogs/liquiglide-nonstick-coating.jpg)

In terms of physical properties, packages with light yet solid structures are being experimented in the field to achieve efficient designs with less material use. Material qualities are being improved as well, such as repelling coatings that keep packages dry and less friction coating for easy pouring of sticky products like ketchup (Figure 2.14). Also through the innovations in processes, the spent energy amount is being reduced, i.e. self-cooling or heating packages.

On the other hand, as mentioned earlier in the considerations of packaging design, several aspects can be explored from the user perspective, including the scenario of use, context and product-user interaction. Questioning the places that package will be used and the personas that will use these packs constitute a starting point for this approach. Packages that are easier to use, convenient to carry or have extra functionality for latent needs are developed through the discoveries regarding the

user. Figure 2.15 presents an example of inclusive packaging that is intended for users with disabilities who have difficulties in opening packages. The one-hand opening band aid design is also convenient for its context of injuries.

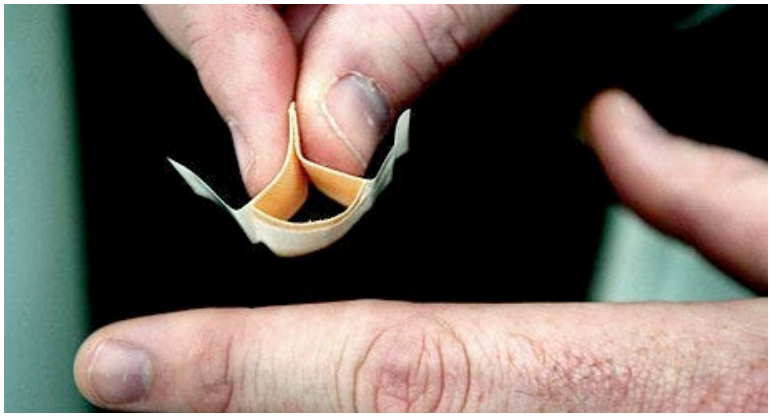


Figure 2.15 – Clevername Plasters (retrieved from: http://image.guardian.co.uk/sys-images/Arts/Arts_/Pictures/2007/12/19/bandaid460.jpg)

The lifecycle of the package presents another point to focus on, as the improvements within the steps may lead to more sustainable practices as a subsidiary achievement. The packaging that takes up less space when stored, for instance, reduces the amount of containers during the transportation, therefore decreases the carbon emissions.

In short, there are multiple points to explore in the packaging design field that present space for innovation and progress. Although some of the aspects could be considered too technical for the industrial design practice such as the material development, some of the points – like the lifecycle analysis – actually may hold potential to be exploited in the product design process.

### 2.4.3. The Nature Model of Packaging

Nature equips several forms, structures and strategies as packaging solutions within animals, plants and minerals. With a specific focus on the protection of the offspring that ensure the continuity of reproduction, nature generates packaging that is optimised individually in accordance with diverse conditions.

Figure 2.16 – Package examples from nature incorporating various strategies

Nature faces similar challenges to that of humans in terms of packaging, yet it does not distinguish between the product and it's packaging, but instead follows a more holistic approach by planning the whole sequence from production to delivery (Dawes, 2009). To understand the nature's model on packing things, the example of a seed can be investigated. The seeds comprise a whole with their packages and are contained in diverse geometries and various numbers. Within their well-packed environment, the seeds are protected, grown, carried and conserved even inside of the stomach of an animal. They indicate the status of their ingredients by ripening and are easily opened for the disposal of items. The seeds are dispersed through several agents and finally the packaging dissolves in nature after completing its task.

A selection from nature packages is compiled in Figure 2.16, where each product employs unique strategies. For instance, lettuce is a leakage-proof package that is comprised nearly full of water. Honeycomb is another distinct package that utilises a specific geometry for a light and strong structure and space efficiency. Bananas are held together and can be ripped off singly. In overall, nature packages offer a variety of solutions that may be of use in manmade packages.

In her interview titled 'The Packaging Genius of Nature', Jane Fulton Suri (2013, p. 26) refers to the nature's packaging approach from design perspective as following:

> '[Nature]…lets us explore questions such as: What needs protection? From what? Where will it travel? And how? Who will engage with it? In what contexts? What needs to be communicated – perhaps emotional things, like brand and freshness, as well as functional issues? What other artifacts will relate to it? How will it be used, stored, reused or disposed of? ... This is where more radical innovation happens, because we begin to rethink what packaging is.'

Compared with the manmade packaging lifecycle, nature has a method of solving production, packaging, distribution and recycling within a complete cycle. Thus, it has already achieved what the industry aims for. At this point, nature inspiration can be beneficial in designing sustainable packages that are both elegant and functional.

### 2.4.4. Packaging Design as a Research Field for This Study

Through the mentioned issues – namely nature inspired design, design paradigms and packaging design – an overlapping space can be seen in terms of challenges and solutions. The examples illustrate that manmade packages have benefited from natural packaging models, paradigmatic mechanisms and structures profoundly.

A simple example to the nature and paradigms inspired package is the clamshell packaging, which originates from the clamshell form of bivalves and utilises the hinge paradigm in its one-piece structure (Figure 2.17). Observing its qualities in

terms of protection, reopening/closing and sealing, humans made use of clamshell paradigm to create compact and convenient packages for their purposes.

Figure 2.17 – Clamshell packaging inspired by clamshell and hinge paradigm

Similar to the clamshell example, there are a number of packaging examples that employ nature paradigms as a concept: collapsible containers with telescope paradigm, blister and bubble wrap packs with bubble paradigm and stacking cups with objects-nested within-objects. Many functions or properties that are borrowed from nature or manmade paradigms can be found in the packaging field and these inspirations mostly prompted to novel ideas and improvements. Therefore, the study of nature and paradigms may lead to new solutions in packing problems through the use of forms, structures, materials and strategies.

As mentioned earlier, the current focuses in packaging design include sustainability and innovation, both of which are covered and supplied by nature inspired design (DTI Global Watch Misson, 2007). Regarding this issue, Bar-Cohen makes an in-depth analysis in his book ‘Biomimetics: Nature Based Innovation’ and indicates the variety of structures, techniques and process in nature packages that could be transferred to packaging products (Bar-Cohen, 2011). However, he also states that the application of these biological patterns that associate form, structure and function are still lacking.

A study within the intersection of these topics includes further advantages regarding the design process. Beyond simple applications of solutions found in nature, nature inspired paradigmatic thinking may challenge our existing approach to design and open up a new perspective in our problem solving methods. As Timothy McGee, a biologist and biomimic, mentions, packaging in nature presents various mental

models, which can alter our perception of what's possible in design, thus may change the things we produce as well as the way we think and the way we produce (McGee, 2013). To conclude, nature and paradigms approach as a method in design holds a potential for packaging field both as a collection of ideas and a model of thinking. In the next section an idea generation process on packaging will be explored.

### 2.5. An Investigation on an Idea Generation Phase within the Design Process

This section presents a packaging design ideation process from professional practice to explore the dynamics of the idea flow throughout a brainstorming session. The project brief is the design of innovative concepts relating to ice cream packaging. Commissioned by a packaging manufacturer, the packaging design concepts were developed and sketched by Dr.Hakan Gürsu of Designnobis product design studio.

As the context of this thesis focuses on the idea generation stage, the presented parts include only the ideation phase of the product development process. Nonetheless, these concepts were further refined throughout the later stages in the project and evolved into final products. Before the ideation phase, problems related to existing products were defined and project needs and objectives were identified through user research and manufacturer's insights. In that stage, it was found out that;

- the bottom part of the ice cream cone is the fragile part of the product and it is mostly broken through the transportation/storage/display processes
- the top part of the ice cream packaging is difficult to seal with the existing cover
- the cone shaped ice cream on top in some products needs a solid protection, some plastic caps are employed in market, yet they create more plastic waste
- cone ice cream is usually packaged within a cone paper, therefore some basic geometries and folding methods with paper can be explored
- ice cream package is generally tear-opened and disposed, thus the post use opportunities for more sustainable practices can be examined
- as the ice cream consumption occurs mainly through summer, outdoor activities and social concepts may present a space for innovation

Since the packaging company was manufacturing paper packages, the ideas were focused on paper-based solutions initially. However, through the free flow of ideas, the concepts progressed towards more radical approaches by shifting the paradigms. Beside the single package, multiple item relations were explored and even the ice cream cone itself was altered. Ideation and brainstorming sessions were carried out in 2-3 days within a week and each session took about 3-4 hours. Almost all of the sketches were quick drawings with communication purposes, yet their quality was found appropriate for a concept presentation after some colour work.

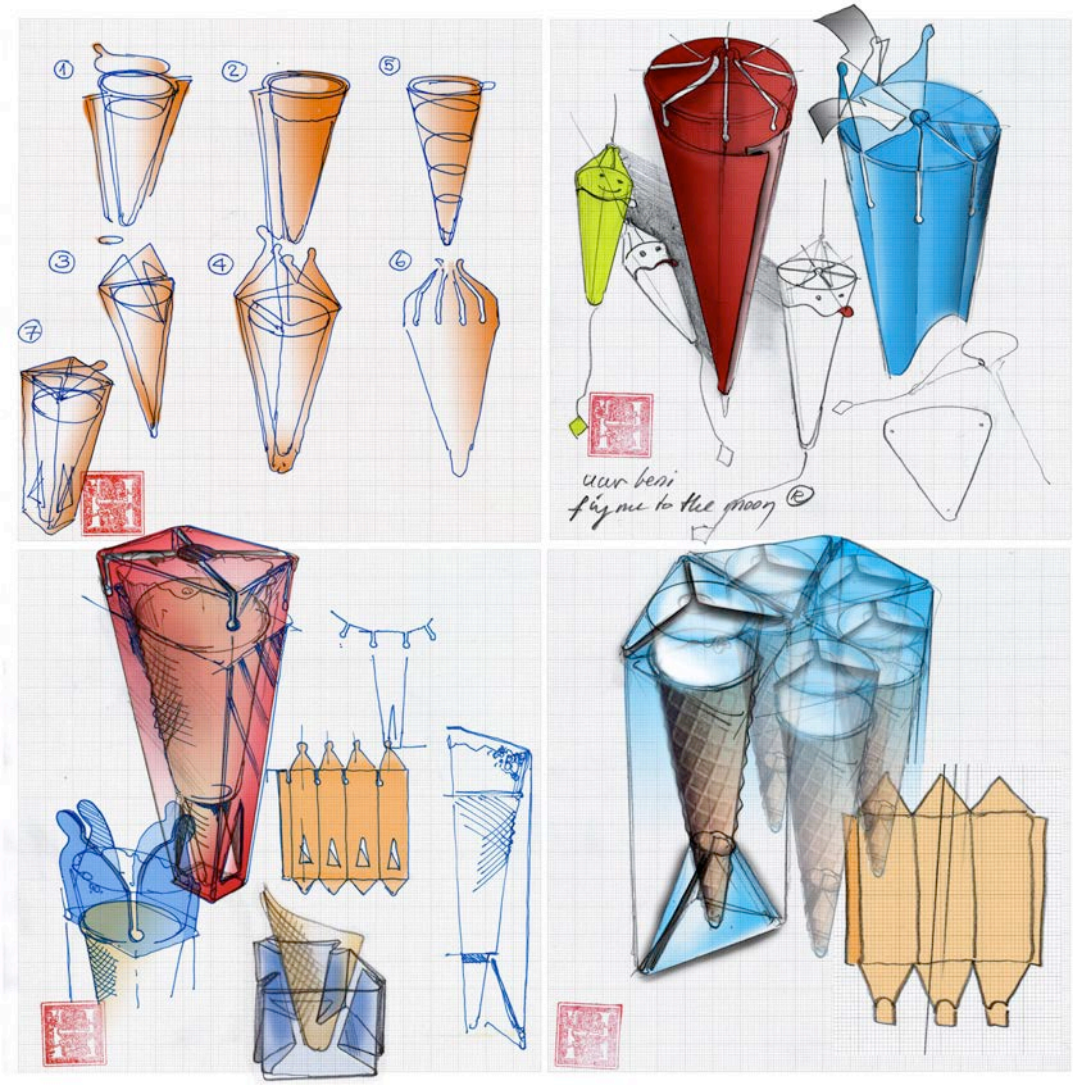


Figure 2.18 – Initial ideas exploring basic geometries (image courtesy of Designnobis)

The brainstorming session started out with the exploration of possible geometries for enclosing the ice cream cone (Figure 2.18). Various strategies were incorporated for packing and opening: a pack split in two, pyramids with triangle or square bases that open like petals, stripe open or thread open packages. These early configurations were sketched as individual concepts to generate ideas upon. Here, the ideas make use of basic forms as paradigms, such as rectangles, prisms and cones.

For instance, a rectangular package that folds and protects the bottom of the cone was devised. Using a similar folding strategy, a triangular shape was explored with its multiple formations. Lastly, a peel-off pack that was inspired by banana was portrayed as a kite with a character on it. As it can be seen, while the ideas were built, the focuses started to shift towards objects of entertainment.

The next group of ideas examines diverse approaches within the ice cream concept. Inspired through the context of use, various considerations were effective in the development of these ideas. The ‘love theme’ that is used for marketing purposes in ice creams was exploited in a couple of ideas.

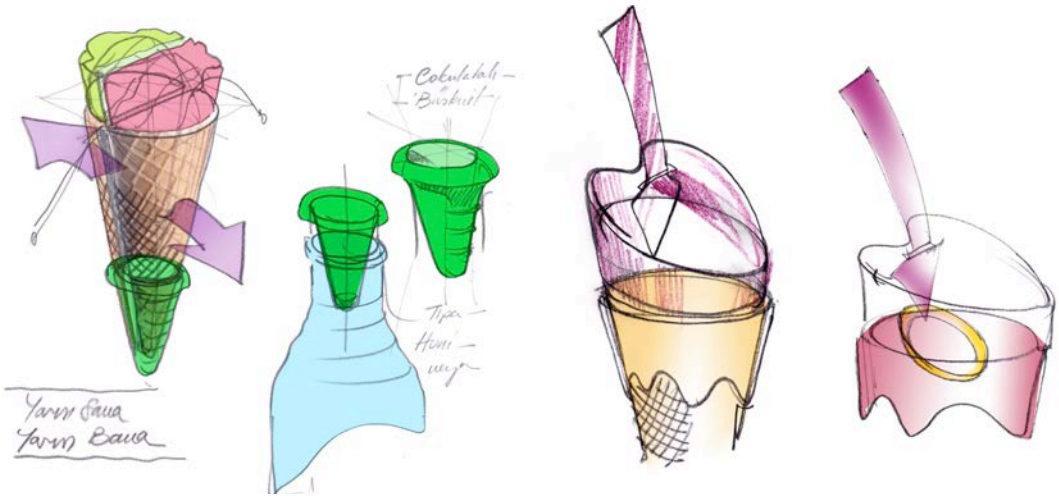


Figure 2.19 – Concepts with Love Theme (image courtesy of Designnobis)

‘Two halves’ concept (Figure 2.19) suggests a half split ice cream in a single pack that was bound by a cone shaped chocolate biscuit or a plastic piece that can be later used on bottles. Two equal parts or twins paradigm was used as an analogy for ‘two

lovers'. Similarly, a surprise pack that may include a ring was developed with a heart shaped protective cap on it. The idea may refer to an oyster with a pearl that potentially holds a precious item within a closed casing (Figure 2.19). As presented, this theme has marketing objectives alongside its design goals.

Moreover, the post use approach was utilised to generate ideas that employ the parts of package as an object with a new purpose. 'Toy creatures' theme is an example in which the protective caps are shaped as creature heads or legs, thus the caps of two ice cream packs turn into a creature (Figure 2.20). The idea can be effective in terms of both preventing the plastic waste and creating an interest towards the package.

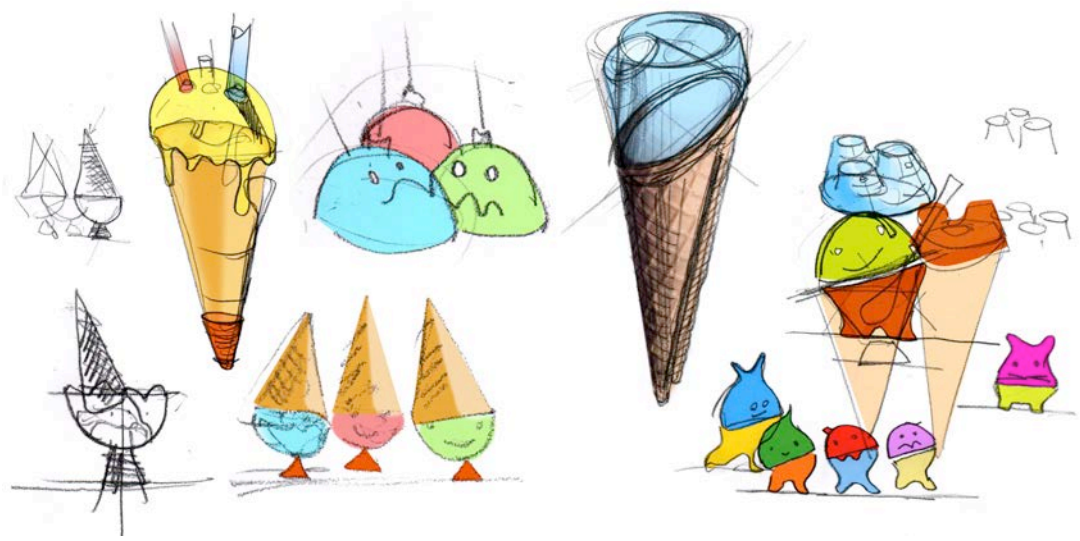


Figure 2.20 – 'Toy Creatures' Theme for Post Use of Packages
(image courtesy of Designnobis)

Another context-driven idea group (Figure 2.21) illustrates the creative concept development within the brainstorming process through the exploration of user groups and activities. Further examining the post use approach, the plastic caps in form of various hats are suggested as mini accessories or finger toys in 'King's Cream' concept. On the other hand, a social context was inspected in 'Party Poppers' idea that derives from a scenario where a number of ice creams were consumed and their package cone was used as lighting elements.

'Torch' concept brings this idea forward and makes use of the package as a handheld object. By including a tea light, the ice cream package is converted to a torch to be used in outdoor activities such as concerts. Similarly, 'Horn' concept features the cone-shape to create a horn that can be entertaining in sports games (Figure 2.21). The idea suggests an outer skin to be torn off by employing the object-within-object paradigm.

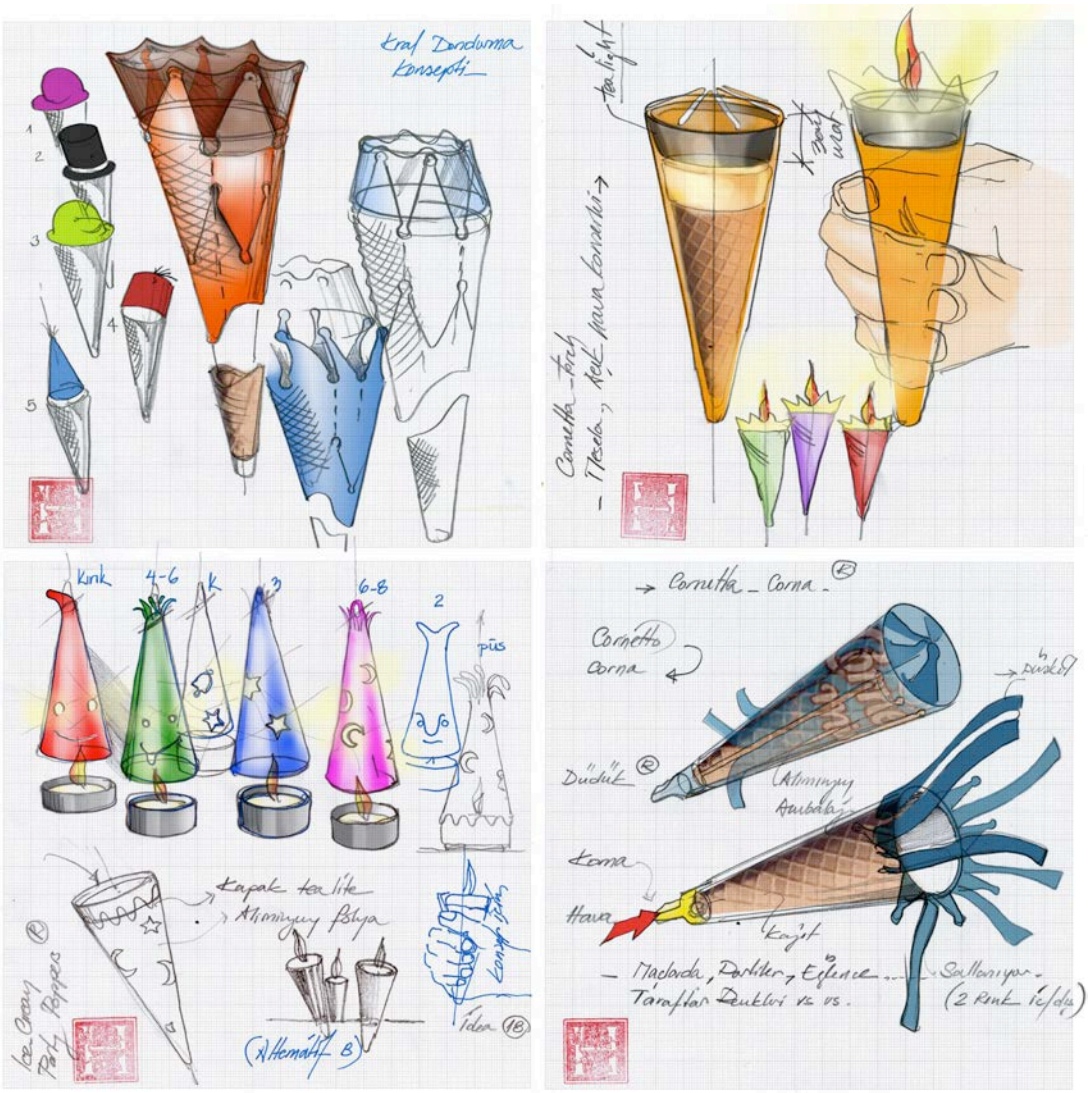


Figure 2.21 – Context-driven Concepts
(image courtesy of Designnobis)

Through the ideation relating to different uses, multiple object relations were investigated as well to inquire the space for improvement. A six-pack packaging was

developed offer a novel arrangement for ice creams. Additionally, examining the prism geometry, designers generated a transparent bundle pack that gives away one ice cream for four. Biscuits were suggested as a solution to sealing the top parts of the ice cream package (Figure 2.22).

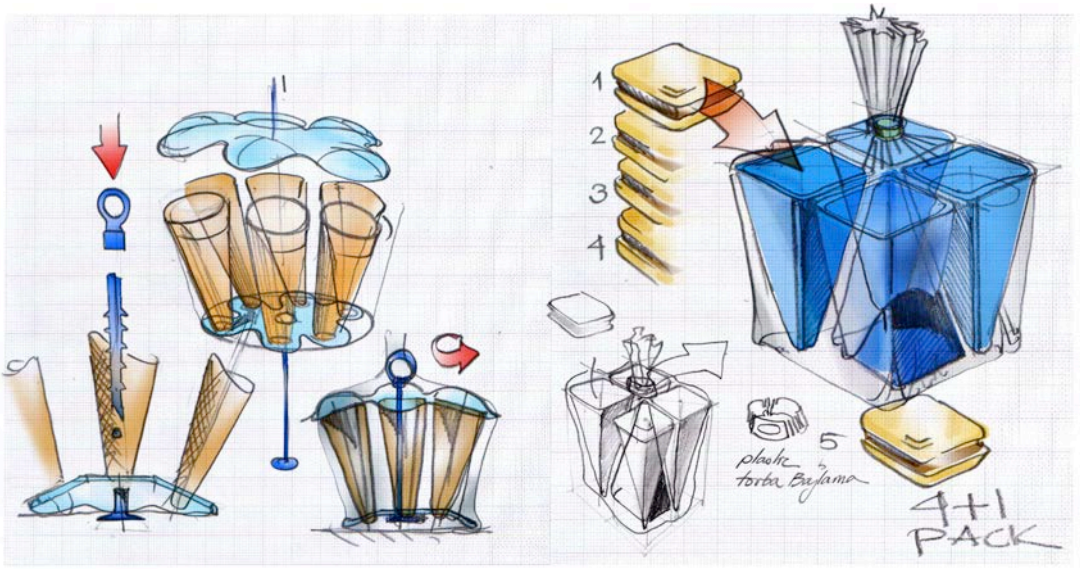



Figure 2.22 – Packaging Concepts for Multiple Ice Cream Packs
(image courtesy of Designnobis)

In further stages of the idea generation sessions, more liberated concepts were developed through the redefinition of the problem. Questioning the way ice cream cone is shaped, the designers intervened in the process and ideated on the ice cream and waffle itself. 'Ice-cuit' concept presents a roll shaped ice cream within a waffle that can be broken into slices. Additionally, alternative ice cream cones were experimented; such as the half split waffles that have chocolate pieces in their connecting parts (Figure 2.23). In these ideas, the basic forms and 'parts creating a whole' principle was employed as strategies.

As can be seen, throughout the ideation process, generated ideas and concepts employ various paradigms and principles that are drawn from the vocabulary of the designers. Originating in both nature and manmade world, the use of design paradigms occurs naturally without any specific intention or focus on the paradigm itself. Designer's experience and knowledge plays an important role in the

accumulation of the paradigms as a library and their utilisation through the design process.

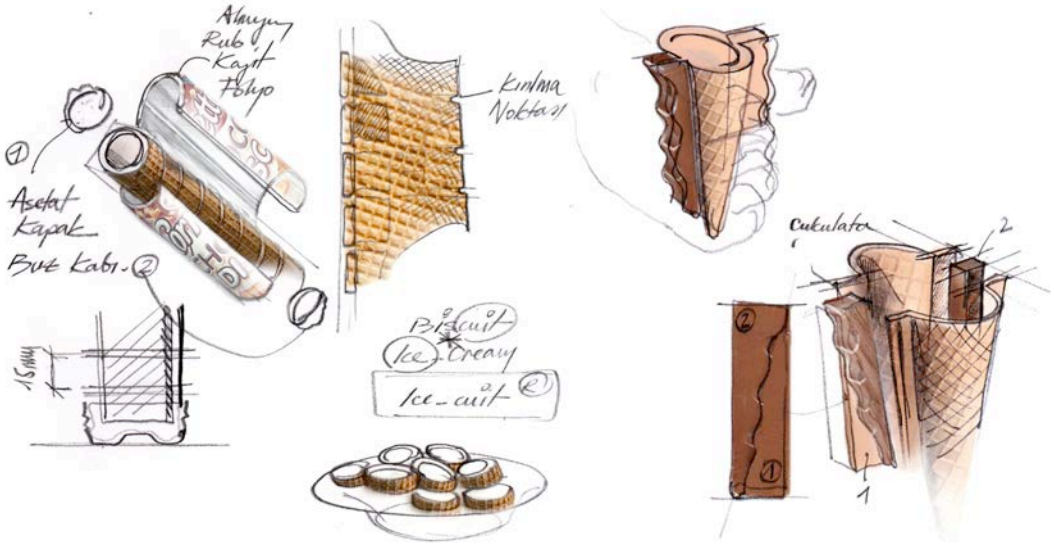



Figure 2.23 – Concepts that Redefine the Ice Cream Cone Itself (image courtesy of Designnobis)

Throughout the session, it can be observed that the use of a multitude of strategies and metaphors in the ideation stage enables flexibility in thinking and the diverging ideas explore a range of possibilities within the design brief. The idea flow also shows the multidirectional movement in the brainstorming phase. Moreover, the process outcomes illustrate that the generated concepts started out as packaging design ideas and advanced toward more liberalised designs. This is due to the paradigm shift in ideation that is achieved by redefining the problem.

In overall, the example provides insights on the creativity and innovation through the idea generation stage with the variation and shift between the concepts and demonstrates the use of paradigms in product development process. The next section introduces selected packaging examples that were inspired by nature and design paradigms.

## 2.6. Nature and Design Paradigms Inspired Packaging Design Examples

Packaging designs inspired from the nature and paradigms illustrate the application of the approach and its benefits. The selections of reviewed cases present diverse gains such as self-communication reduced material use and environmental impact and more user friendly design.

### ‘Expired’ Medicine Packaging

‘Expired’ concept is inspired by the way bananas sign their decay with brown spots and use this simple analogy to intuitively indicate its expire date. Aiming to achieve a more user friendly and safe medicine pack, designers Kuen Chang and Jin Ko of IDEO created a self communicating and state indicating accessible medical pack (Figure 2.24).

Figure 2.24 – ‘Expired’ Concept by IDEO that utilise banana analogy (retrieved from: http://www.designs-on.com/issue/packaging/)

### Self-Sealing Bicycle Water Bottle

With a quest to redesign the bike water bottle, designers at IDEO analysed the traditional water bottles and observed the two step use that require the user to bite-pull out the dispensing spout prior to drinking. Seizing this opportunity for improvement, they introduced a new dispensing approach inspired by the tricuspid

heart valve. The bottle features a self-closing spout that enable a squeeze-open container, therefore an easy to use design (Figure 2.25).

Figure 2.25 – Self-Sealing Bicycle Water Bottle inspired by tricuspid heart valve (retrieved from: http://ideo.com)

**Vitalis PET Water Bottle**

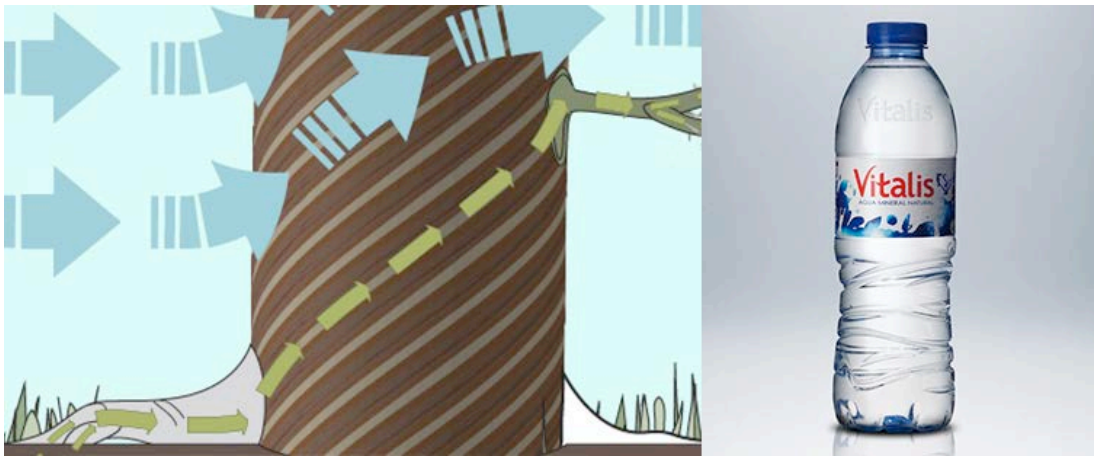



Figure 2.26 – Vitalis Water Bottle inspired by spiral fibres on the whitebark pine (retrieved from: http://www.asknature.org/product/b5dc4030c48e41b03442d34aecdf46b4)

A major bottled water brand in Portugal, Vitalis took the challenge to create the lightest PET water bottle on market with minimum material use. Using biomimicry approach, design team drew inspiration from structural advantage of spiral fibres on

whitebark tree, in other words, the packaging design utilised the spiral and helix paradigms.

As the natural model of spiral growth enables a stronger trunk with more flexibility provided by helical structure (AskNature.org, n.d.), nature inspired Vitalis water bottle is lighter, stronger and uses less material. Through the optimisation of bottle's design, efficiency and sustainability are achieved. It also resulted in an exclusive form that enhances the brand identity and saves 250 tons of material per year (Figure 2.26).

The presented literature review provided foundation for the study to build upon the themes of nature, design paradigms and packaging and enabled to associate the topics. Examined tools and methods were used in the preparation of the field study and the card deck tool. The next chapter explains the followed methodology for the analysis and development of the used tools and techniques within the context of the study.

# CHAPTER 3

# METHODOLOGY

This chapter presents the research structure and explains the methods used for data collection and analysis, and the development of a card deck tool as an ideation tool for this research. The chapter includes detailed information on the preliminary study, the primary research, the development of the Nature Design Paradigms Card Deck and its integration to design process, the evaluation questionnaire, sampling and thematic analysis in particular.

## 3.1. Research Stages

Nature inspired design is an approach that is favoured by designers through ages in a variety of forms. On the other hand, its study as a systematic method for product design process emerged in the 1960s with the bionics discipline and popularised with the biomimicry practice that was put forward about 2000s. Today, the methods and tools for utilising nature solutions in manmade products, systems or processes are still being developed. This research focuses on the use of nature strategies in idea generation process in product design and refers to ‘nature inspired design’ as an umbrella term to inquire various ways that designers are influenced by nature. The study also employs the design paradigms approach to investigate the use of metaphors and strategies in the design process and suggests it as a method in creative ideation. As the paradigms are derived from the nature and manmade objects, the proposed approach combines these two perspectives under the title of ‘nature design paradigms’.

For this research, an ideation tool in the form of a card deck was created to explore this approach and its effects on idea generation process in product design. The NDP Card Deck was integrated into the design process within a workshop format and the exercise was conducted among second year industrial design students at METU. The study is focused on packaging design and aimed to develop creative design solutions and concepts through the use of strategies and paradigms provided by the card deck tool.

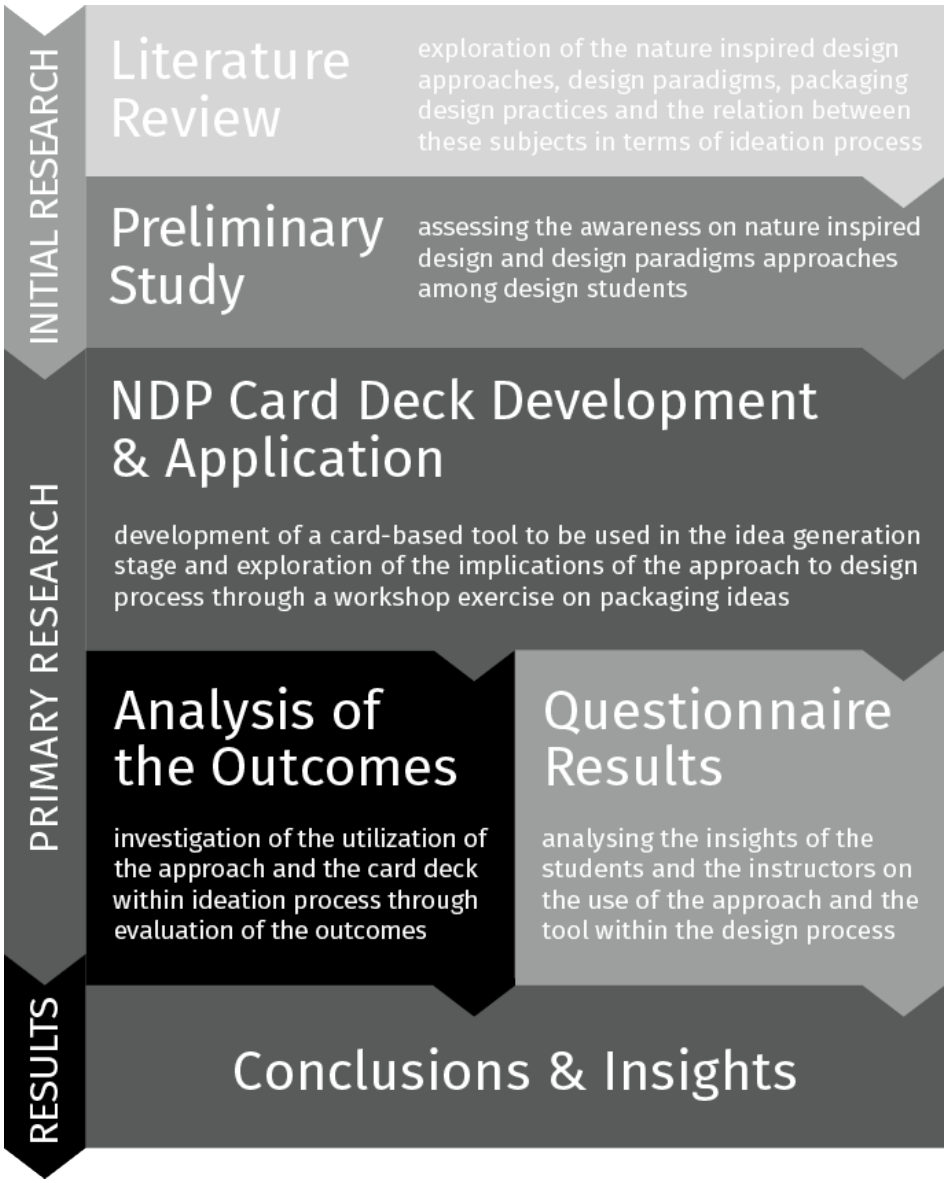



Figure 3.1 – Research Stages

The research is comprised of three main parts: literature review, preliminary study and primary research. The preliminary study is aimed to assess design students' awareness on nature inspired design and design paradigms. The primary research includes the development of the card deck exercise and the analysis of results both from the project outcomes and the evaluations of the students. Figure 3.1 illustrates the structure of the research and its stages.

## 3.2. Preliminary Study

An initial survey was conducted among design students in order to assess the awareness on nature inspired design and design paradigms. The preliminary study is aimed at exploring the level of knowledge and deriving from the responses to contribute to the primary research. This data also enabled to observe the change in their perception of nature, paradigms and their relation to design. Prepared in the form of a questionnaire, the survey is comprised of questions and design problems. Preliminary study steps including sampling, data collection and analysis are explained in the following sections.

### 3.2.1. Population and Sampling

A pilot conduct was made at a design event held at İTÜ ID Department and 54 design students from 12 design schools in Turkey, whose profile was distributed between 2nd, 3rd and 4th years, participated in the study (full list is presented in Appendix A). The results showed the nature inspired design awareness and ability to recognise and use design paradigms among design students. However, the initial version of the survey lacked the assessment of their personal experience. Therefore, the first question was added in the revised version to explore the students' previous practices and perception on nature inspiration in design.

The revised questionnaire was carried out prior to the workshop exercise among the second year industrial design students at METU, which consisted the sample group of the field study. 39 out of 41 students contributed to this study.

### 3.2.2. Data Collection: Preliminary Survey

Designed questionnaire was comprised of two main parts; the first part aimed to survey the knowledge and experience of nature inspired design concept, whereas the second part intended to evaluate the ability to generate variations with design paradigms. The survey structure has both open and close ended questions and design sketch problems. Questions were tested and revised prior to conduct of survey. The questions are presented in Table 3.1.

Table 3.1 – The Preliminary Survey Questions

| |
|---|
| Question 1. Do you inspire from nature in your design process? If so, could you exemplify?<br>Question 2. Do you know of any approach or method that is focused on nature inspired design as a discipline? If so, please explain.<br>Question 3. Could you name any examples of nature inspired design?<br>Question 4. Please check the words you find relevant to nature inspired design.<br>*Word Set 1:* Users, Function, System, Form, Process, Biology<br>*Word Set 2:* Materials, Innovation, Structure, Sustainability, Energy, Manufacturing Techniques<br><br>Essential solutions including basic forms, functional relationships and behaviours that embody fundamental design strategies are called ‘design paradigms’. Being a collection of a thousand different great little ideas, they constitute the basic building blocks of design (Wake, 2000).<br><br>Question 5. A number of ways can be utilised to make an object open/closed. For example, a hinge or a snap fit detail can be employed. What else can be applied to achieve that aim?<br><br>Question 6. An object can change shape and size through use of bellows. Which techniques can you think of to be used in order to have objects change its shape/size? |

Complemented by figures to illustrate specific paradigms with a basic form, two questions were presented as a spread page to be filled out by students. Participants were free to express their ideas according to their preferences, in visual and/or written language. The questionnaire was prepared in English and included in Appendix B as full spread.

### 3.2.3. Outcomes and Their Analysis

For the first part of the survey, the data analysis was made using both qualitative and quantitative analyses. The questions were classified within themes to enable making inferences and representing the outcomes graphically where possible. The results showed the students' perception on nature inspired design and their experience in the subject.

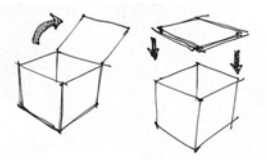
The outcomes regarding the design paradigms section of the preliminary survey were analysed through their quantity and content. The students provided answers using solely written or visual language or utilising both. A sample survey outcome is presented in Figure 3.2. The findings revealed their skills on using metaphors and analogies in idea generation process and supported the main study. The answers to the preliminary survey questions and the analysis of the findings will be provided in the next chapter (see section 4.1).

## 3.3. Primary Research

The primary research consists of these three major parts: the development and the implementation of the card deck exercise, the analysis method for the outcomes and the evaluation. These steps are presented in detail through the following sections.

### 3.3.1. Development of the Nature Design Paradigms Card Deck

Regarding the tools and methods for utilising nature strategies in design, a variety of choices are available as presented in the previous chapter. Within the context of this

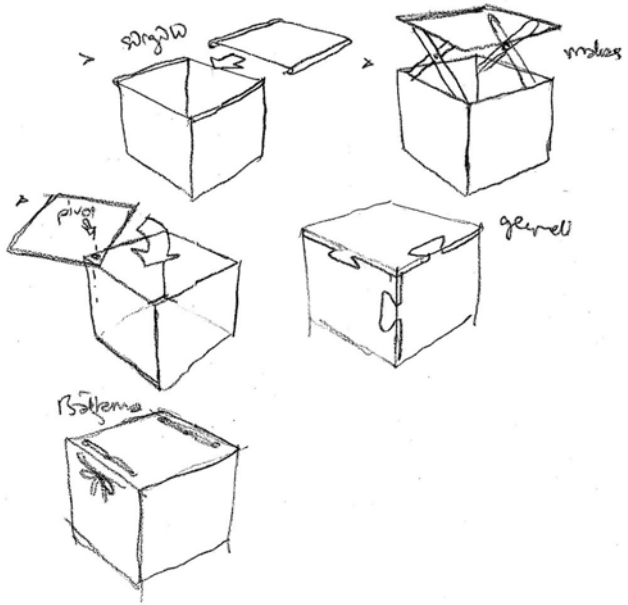


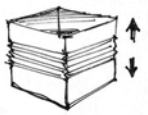
Şekil 1

*Temel tasarım stratejileri içeren basit formlar, fonksiyon ilişkileri ve hareketlerin oluşturduğu temel çözümler 'tasarım paradigmaları' olarak adlandırılır. Binlerce farklı, mükemmel, küçük fikirlerin bir araya geldiği bu koleksiyon, tasarımın temel yapı taşlarını teşkil eder (Wake, 2000).*

**5. Bu doğrultuda, yaklaşık küp hacminde bir şeklin açılır kapanır olabilmesi için çeşitli yöntemler kullanılabilir. Örneğin; menteşe veya sıkı geçme yöntemleri izlenebilir (Şekil 1). Bu çeşitlendirmelere ek olarak neler düşünülebilir?**

(Sözcüklerle ifade edebilir veya görsel anlatım kullanabilirsiniz)



Şekil 2

**6. Benzer bir biçimin şekil değiştirebilmesi gerektiği takdirde ne gibi yöntemler kullanılabilir? (Örneğin; körükle büyüyüp küçülme (Şekil 2))**

(Sözcüklerle ifade edebilir veya görsel anlatım kullanabilirsiniz)

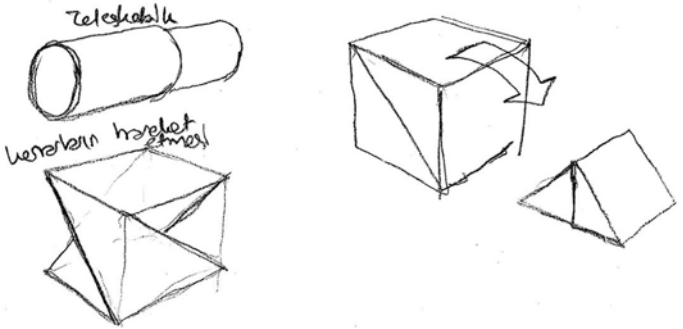



Figure 3.2 – A sample outcome from the preliminary survey

thesis, however, both nature solutions and design paradigms were explored to be employed in the design process. In order to enable the use of these overlapping strategies in the idea generation stage in a practical way, the development of a tool was necessary.

In the initial phases of the research, several methodologies were considered for utilising the paradigms: a poster where strategies were collected and classified under themes and presented with pictograms, a presentation which introduced the paradigms thinking and allowed the participants to find their own paradigm inspirations from nature or objects or more physical tools such as the use of method cards. Prior to specifying the methodology, the paradigms from nature and objects were compiled and an index of strategies was formed using several sources, as it will be explained in the upcoming sections.

An important point in the selection of the form of the tool was the integration of the approach to the idea generation stage and the capabilities of the target group. For the integration, a hands-on tool that could inspire and assist the design process was found more measurable in terms of its use and effects. In addition, the study required an easy to utilise tool in terms its content in both nature and design paradigms, as the specified users – whether students or inexperienced designers – usually do not have any background in biology and lack experience in design and ideation processes. Therefore, it would be practical to have a tool that does not require much knowledge or experience.

To communicate these principles as a tool with abovementioned considerations, a card-based form was found suitable for this study. Thus, the Nature Design Paradigms Card Deck (NDP Card Deck) was developed. However, it should be noted that the tool was a means to investigate the aims and objectives of this study, rather than being the focus of the research. Moreover, the study focused on the process instead of an end product as it is the initial step in the development of the card deck tool that is open for improvement. The following sections explore these steps in the development of the NDP Card Deck and explain the process in detail.

#### 3.3.1.1. Method Cards in Design Process

Use of method cards as a tool that assist design ideation process is a common approach in design field. There is a wide range of card decks with several different focuses such as sustainability, design methods, materials etc. Method supports design process by offering inspirations and reminding general concepts and strategies. According to Wölfel and Merritt (2013) who discuss the design dimensions for card-based design tools, the reason that physical cards have been popular design tools is not only as they are simple, tangible and easy to manipulate, but also they make the design process visible and less abstract.

Examples of card-based tools are examined to explore their properties in terms of design and use. Method Cards developed by IDEO, a global design firm, illustrates a card deck that is unstructured and non-categorised (Figure 3.3). Used to provide various design strategies within any stage of design process, the IDEO Method Cards presents a neat example regarding both its physical qualities and contents. Additionally, the cards are also available in digital format and could be downloaded to mobile devices in form of an application.


Figure 3.3 – IDEO Method Cards (retrieved from: http://ideo.com)

Another example is the Design Play Cards by Eco Innovators, which is a context specific card deck with a focus on sustainability. Offering a more systematic

approach with categories and instructions, the deck has a relatively more structured use. As for its contents, Design Play Cards includes diverse amount of strategies and paradigms from design and sustainability fields (Figure 3.4).


Figure 3.4 – Design Play Cards by Eco Innovators (retrieved from: http://www.ecoinnovators.com.au/)

A related application regarding the subject of this study was implemented by Volstad and Boks, who employed the biomimicry approach to create a card deck to inspire the design process (Volstad & Boks, 2012) (Figure 3.5).

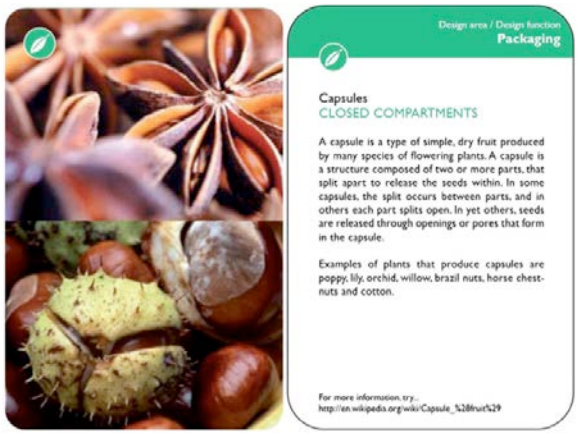



Figure 3.5 – Biomimicry Card Deck (adapted from Volstad & Boks, 2012)

Suggesting the development of card decks in various product categories, the research presents the considerations for the forming of the cards and the implications of their use through pilot exercise. Although the researchers provide exemplary cards in their research paper, the card deck is prepared for research purposes and is not yet available as a tool for designers and researchers to utilise in design process.

Considering the dimensions and elements found in the design of card-based tools with the inspection of existing card decks, the paradigms were analysed with employed strategies, organisms or mechanisms to provide both informational and applicable concepts. The next section discusses the design considerations of the card deck.

#### 3.3.1.2. The Design and the Content of the Card Deck

As widely utilised tools in design process, the design and the use of method cards were analysed to reveal the existing considerations and patterns. In their study on method cards, Merritt and Wölfel (2013) discuss the design dimensions of card-based design tools. The specified criteria include five elements in the design of cards: the intended purpose and scope of use, duration of use, methodology and formal/material qualities. In terms of these aspects, the NDP Card Deck can be described as a tool that is intended for creative idea generation in design within a context of nature inspiration and design paradigms. Placed in the initial phase of design process, the deck is suitable to be used in the ideation stage. For the integration, a format was outlined with a supportive presentation on the subject, yet the cards can be used independently from this approach. The formal qualities, on the other hand, will be discussed in the upcoming sections.

Steps included in the preparation of the card deck are mainly the creation of the content, the design of the cards and the evaluation of the cards with a focus group to receive feedback and iterate the design. In this section, details of this process will be explained.

#### 3.3.1.2.1. Specifying Strategies and Paradigms

Through the process of arranging the paradigms into a tool format to be utilised in the design process, content creation was a critical part. A broad list of nature and manmade paradigms were derived through the review of the literatures and the sources. With the mapping of concepts, principles and purposes, an index of strategies was created to compare the paradigms, explore their relations and reveal the overlaps. The most referred resources in this process are presented in Table 3.2.

Table 3.2 – The resources referred in specifying strategies and paradigms

| |
|---|
| **Biomimicry Taxonomy by the Biomimicry Institute**<br><br>Evaluated in detail in the previous chapter, Biomimicry Taxonomy is a tool that classifies biological strategies according to the challenges and corresponding tactics and functions. Organised in a hierarchal structure, the guide can be used as a reference tool in inspiring from nature. |
| **Industry of Nature by J.P. Ternaux, 2011**<br><br>Examining nature inspired design examples from various industries, book showcases each instance with its function, strategy, nature inspiration and existing or possible ways of application. Ranging from transportation to furniture and packaging, examples illustrate innovative applications in terms of form, function, materials, production techniques and energy use as well. |
| **Design Paradigms by W. Wake, 2000**<br><br>A sourcebook of paradigms found in nature and design, 'Design Paradigms' book constitutes a library of strategies that designers can benefit in their practice. Presented with illustrations and examples, more than a hundred of paradigms are classified and explained. The book also provides insights on paradigm concept and its utilisation in the design process. |

Upon indexing, this general framework of paradigms was reviewed carefully to select a diverse yet consistent group of strategies. The list of paradigms was converged to a more concentrated collection that could be communicated and utilised easily within a card-based format. In this step, some paradigms were eliminated, while some were combined, revised or rephrased. Concepts that are too abstract such as ‘symbiosis’ or ‘figure ground relationship’ and that are fixed and rather close ended such as ‘screw’ or ‘hydration and dehydration’ were not selected to include general yet conceivable strategies. With the same purpose, paradigms that are different yet similar enough to be collected in a single theme were associated, such as the ‘bubble’ paradigm that may suggest the ‘balloon’, ‘blister’ or ‘foam’ strategies under the theme of ‘inflatables’ or the ‘sapling’ paradigm that combines ‘flexibility’ and ‘elasticity’ principles.

The researcher benefitted from the preliminary survey results at this point in terms of the generated paradigms (see section 4.1.2). As the answers to the questions related to design paradigms illustrated, the proposed strategies included frequent examples such as ‘sliding’ and ‘folding’ and rare ones like ‘skin’ and ‘expansion’. Therefore, the selection of the paradigms resonated with this range that spans from the familiar strategies, such as ‘telescope’ and ‘compass’ to unordinary ones, such as ‘epoxy’ and ‘sapling’.

Paradigms that are most affiliated by participants provide a base in utilisation of cards, whereas diverse paradigms and strategies enable varying between alternative solutions. Also, a gradation of abstraction is available within the selection of paradigms; some are relatively practical and some are rather intangible. All in all, the specification of paradigms was made through the consideration of several dimensions such as form, function, energy and materials. Selected concepts were also evaluated upon their purposes and the final collection was intended to create a mixed repertoire to stretch the thinking.

Paradigms used in the NDP Card Deck consist of general strategies associated with nature and objects that could be embraced in a variety of subjects. From a conceptual perspective, introduced notions and strategies can be discussed on an abstract level as well, independent from objects or organisms. This metaphorical

sense enables to think within a general perception, as the cards essentially deliver ‘in what ways, things meet certain needs’. A similar inclusive approach is present in the preliminary study as well, where forms to be altered are illustrated as cube blocks to prevent possible biases. Therefore, the study does not aim to design the card deck in a strict scope and context.

However, the subject of packaging design is among the focuses of this thesis, as it is already a practical and suitable area to see the effects of paradigms on design process. Thus, considerations regarding package design paradigms were incorporated in the selection and elimination of strategies, where some paradigms were chosen over others, such as ‘modularity’ over ‘aerodynamics’. To conclude, it can be claimed that NDP Card Deck is prepared not specifically for packaging design, but design of packaging especially favours the presented strategies.

The following step was the adaptation of the strategies to be presented in the form of method cards. For this purpose, the paradigms were evaluated upon their functions, aims and uses in nature and objects. Lastly, a brief content on each paradigm was prepared to appear on cards. Each strategy was interpreted into design solutions that can be utilised in the design ideation process with provided images and information. The content creation was also shaped with the general design and the formal qualities of the cards, which are explained in the following section.

#### 3.3.1.2.2. The Design of the Cards

The NDP Card Deck is designed as two sided cards, one side conveying information on a specific paradigm with the other side presenting a related image. Each card describes one paradigm, its incorporated strategies, aims, uses and related concepts (Figure 3.6).

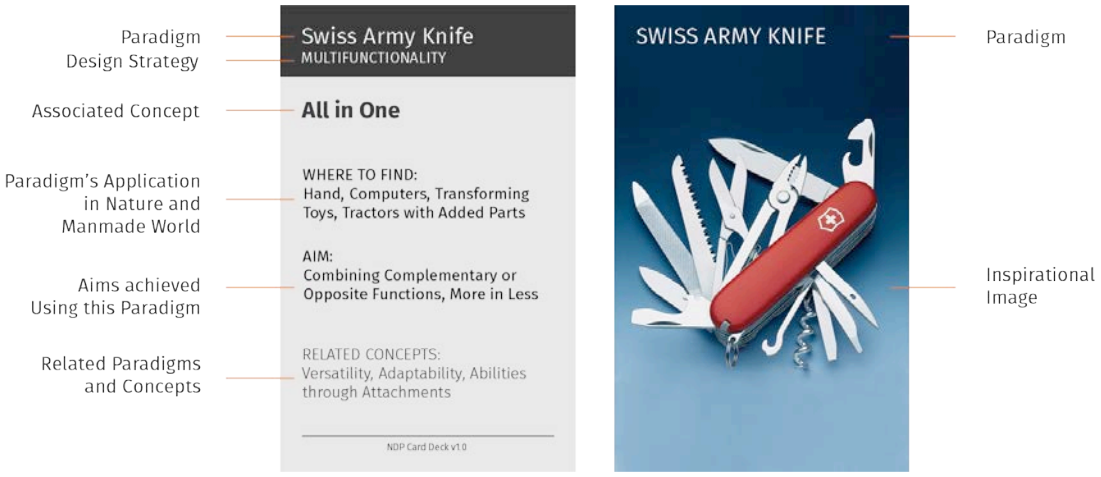



Figure 3.6 – The Design of the Cards with its Parts

Paradigms are introduced with collocating terms that provide an initial idea about the concept. Following the main title, 'where to find' part locates the strategy in both nature and manmade worlds. As Eckert and Stacey (2000, p. 527) indicate, it is helpful to present previous instances of design elements in a variety of different situations for easy use of analogies. Thus, examples from a wide range of areas were included in an extensive number as possible. 'Aim' part lists some of the objectives that can be achieved using the paradigm and enables designers to explore the ideas and relate them to the problem at hand together with the 'where to find' part. Finally, 'related concepts' part constitutes a quick reference to search further paradigms that are linked.

Backside of the cards includes an image associated with the paradigm, along with its name. As Merritt and Wölfel (2013) stated, choosing suitable images for cards constitute an important factor in the design of cards. It is suggested to select images that are abstract enough for interpretation, yet have sufficient detail for users to relate and interpret. Therefore, image selection was made carefully to communicate the idea in a stimulating way. The number of cards was limited to a total of 32 for usability and practicality as a wealth of content was provided within a manageable amount. No categorisation or colour scheme is applied in deck design as each strategy is distinct and can be used independently. A group of cards from the deck is illustrated in Figure 3.7 as examples and the complete deck can be found in Appendix C.

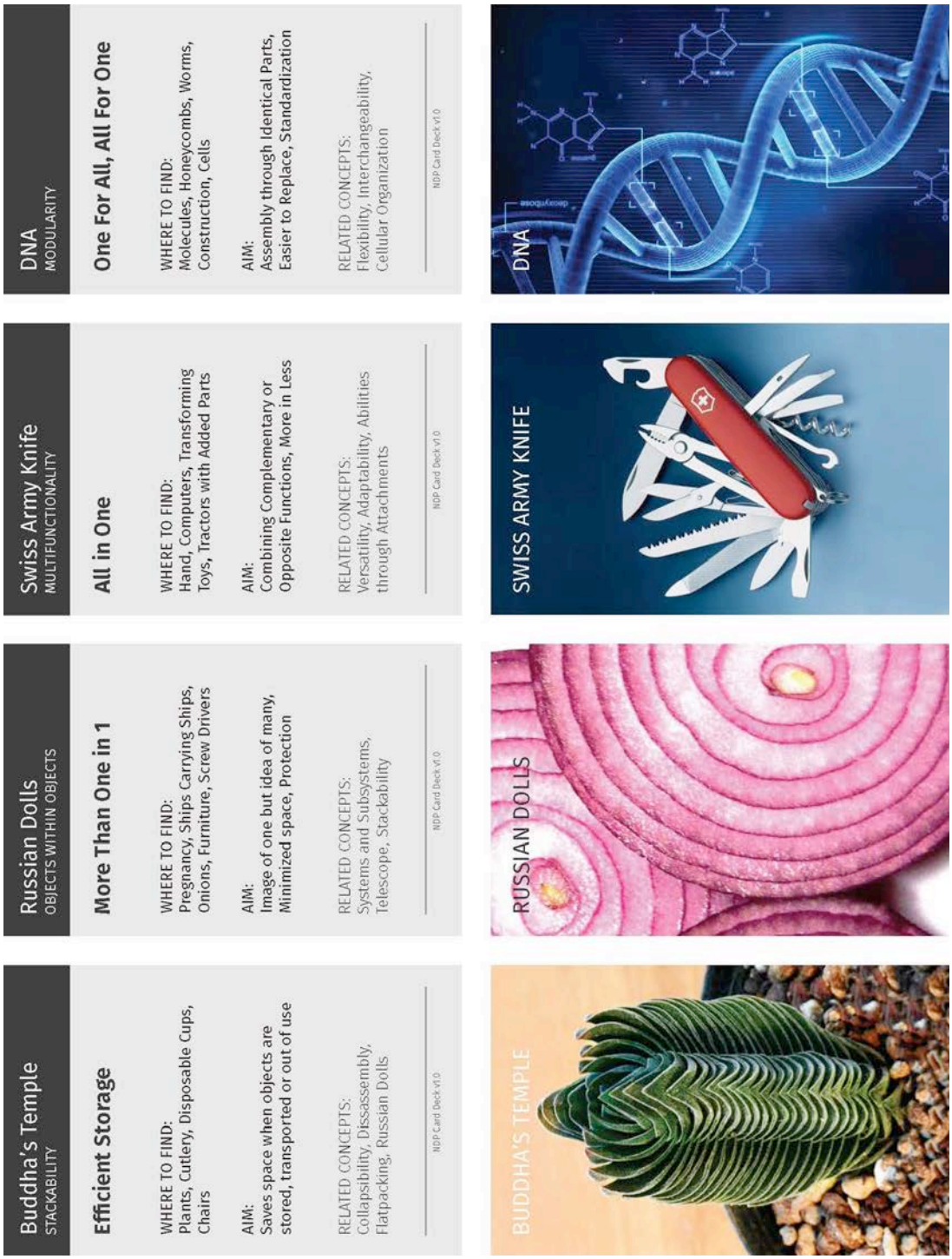



Figure 3.7 – Examples from the NDP Card Deck

The card deck was introduced and provided to the participants in the second idea generation session of the workshop exercise. The utilisation and appropriation of the card deck will be discussed in the following chapter in detail with results of the evaluation of the participants.

#### 3.3.1.2.3. Evaluation of the Design of the Card Deck

The Card Deck was firstly prepared as a draft and the prototype deck was used in a pilot workshop session with a group of students. Evaluation and feedback from the process was used to iterate the card deck into its final design. The pilot workshop was conducted among five participants (two junior and three senior students) and feedback on both workshop process and the card deck was received. The design of cards was evaluated on some major points as their legibility, sides and parts. This process will be explained in the upcoming sections (see section 3.3.2.4).

Cards in the deck were found legible with a clear content and comprehensible vocabulary. Even though, the participants indicated there are still few unknown words, yet the cards communicated the general idea in a proper manner. Comments state that the glossary of paradigms was relevant with the selected images and the conveyed meaning can be associated to design process easily. With regards to the contents, all parts were used, however ‘aim’ and ‘where to find’ parts were especially found useful and referred to.

Double sided design was described as useful and image side with paradigm name was found stimulating. The participants mentioned that it would be limiting to only read the strategies; instead they preferred to first look at the images, and then refer to related info. It was expressed that the image side is more inspirational in terms of form, whereas the information side supports idea generation on a rather strategic level. Additionally, images were found more prominent in some cards, whereas a couple of cards were stated as rather abstract such as ‘tree’ paradigm. This was an intentional design criterion to leave space for interpretation. However, the images selected for these strategies were revised including ‘tree’, ‘cluster’ and ‘twins’ paradigms.

On the connotations, the participants mentioned that the cards were not limited to their suggested use, but were open to free association as each participant made his or her own interpretation. For example, paradigm called ‘Speckles’ used ‘Bananas’ as an image and pointed at the natural decay as a sign. However, banana image inspired a participant in a use context and lead to an idea of a package that opens up as a

banana. All in all, two sides were used in accordance through the ideation, according to focus group. The NDP Card Deck was found 'physical' and 'tangible' as a tool, and the overall evaluation and comments were positive. The total number of cards was also found reasonable to handle. The next section explains the details on the positioning of the exercise.

### 3.3.1.3. Positioning and Expected Use of the Card Deck in Idea Generation Phase

In order to employ the proposed approach in the design process, both nature inspired design and design paradigms approaches were examined regarding their use in design practice. After a detailed exploration of the available tools and methods, the overlaps among processes were revealed.

As tools to support the ideation phase, both approaches follow problem solving steps through analysis and synthesis, parallel to the design process. There are dozens of problem solving methods or models, yet they stem from four major steps: find, devise, execute and check (Petrina, 2006).

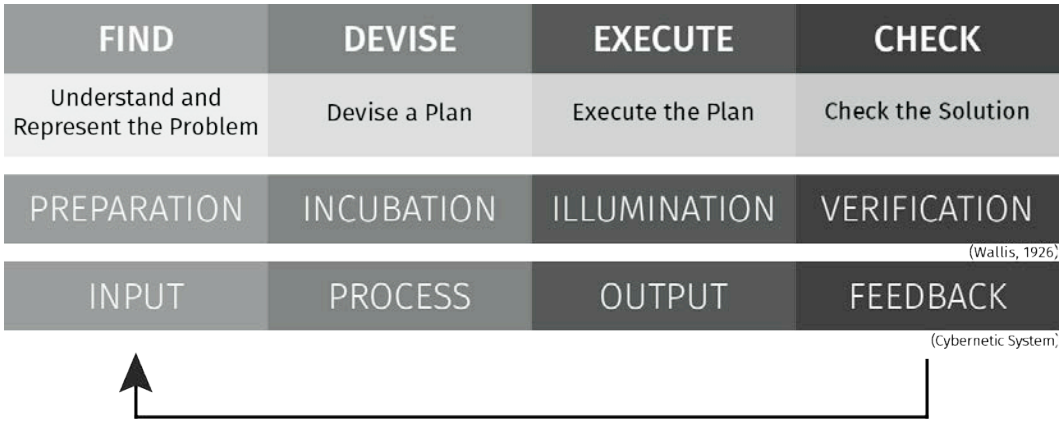



Figure 3.8 – Problem Solving Models in Design Process (adapted from Petrina, 2006)

As can be seen in Figure 3.8, this general process is structured in a way that is applicable with several interpretations in various fields, such as design, engineering

and sciences. Though illustrated as a linear process, the method is applied in a repetitive manner as loops and cycles within an iterative flow. Considering the nature inspired design process and the design paradigms process for design ideation, an overlapping map of processes is derived using the aforementioned methods in Chapter 2. The correspondence between the models is demonstrated in the drawn outline (Figure 3.9).

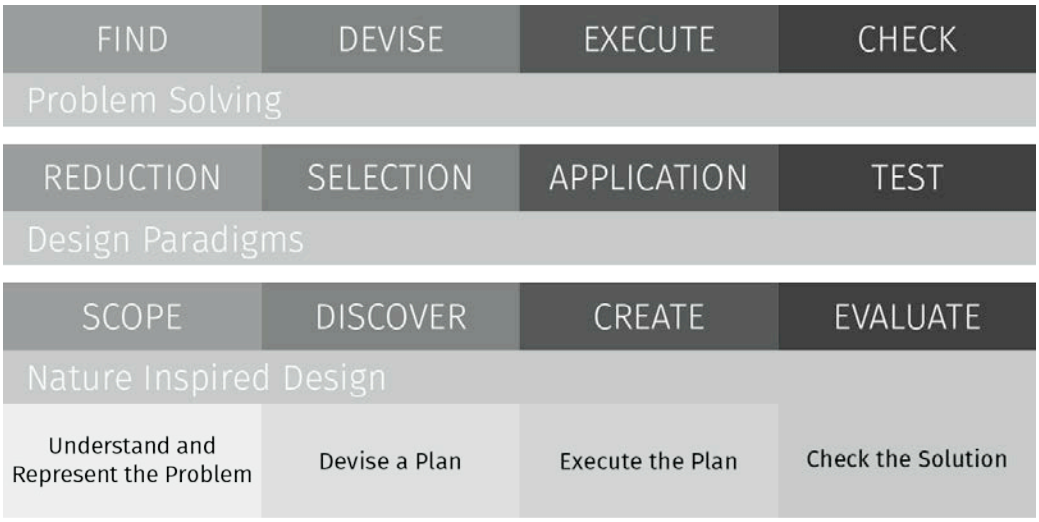



Figure 3.9 – Overlapping Models in Design Process

This four-stepped method was found eligible for the integration of the proposed approach and the card deck tool to design process and the model was tested through the pilot workshop, which was in accordance with the predicted course of ideation. The workshop exercise results also confirmed the expected use of the approach and the deck (see section 3.3.1.3).

### 3.3.2. Integration to Design Process

In order to investigate the utilisation of the NDP Card Deck and its implications, the integration of the card deck within a context in design practice was necessary. As mentioned in the literature review, there are several formats employed in the introduction of nature inspired design tools, such as nature walks and workshops. Due to the structure of the study, a workshop format was found appropriate, as the

exercise both requires an introduction of the subject and a practical session. Therefore, the integration of the card deck is made through an independent workshop that includes a presentation with a design brief and a hands-on design process. Details on the preparation of the format will be explained in the following sections.

#### 3.3.2.1. Pilot Workshop

Before the conduct of the exercise, a pilot workshop was carried out with a group of students in order to test the viability of the approach. A focus group consisted of five design students evaluated the method, the card deck and the exercise. The prepared course included two sessions: the presentation and the ideation session. To compare different applications, participants worked both individually and in groups. They also worked with and without a brief and used the cards in various modes.

During the exercise, the cards were spread on table with their image sides on top. The participants firstly examined each card, looked at the images and flipped back to information side. After checking the cards, they picked the ones they found inspiring and started to sketch for ideas. At the end of the exercise, the process was assessed from multiple dimensions. The pilot workshop revealed several points to be considered, major issues that were referred to are as follows:

*Course of the Exercise:* General layout of the workshop format was found convenient, yet the evaluation showed the need for a group discussion on the context of the packages in brief, beforehand the brainstorming and idea generation stage to address design problems. This point was found applicable and added to the exercise process. Furthermore, it was seen that a critical approach was necessary, thus a discussion session on packages from nature and manmade world was found relevant and placed between the two main sessions.

*Evaluation of the Brief:* The packaging problem specified for the brief of the pilot workshop was the dragee pack. The participants mentioned that idea generation with a specific brief is favourable over working without a brief. However, the outcomes

were successful in both modes, as the open ended session leads to a freely associated and selected package. Even so, the exercise was formed to have a pre-chosen brief to make the process easier, as the designers already lack experience in design process.

*Individual vs. Group Conduct:* Ideating both in group and individual formats, the participants tested different cooperation levels. Feedback shows that a general group discussion on brief including related context, possible problems and points for improvement is necessary in the beginning. Additionally, previous studies suggest that a group work in analysis phase enables a wide range of critiques from both participants and facilitators (Bakırlıoğlu, 2012). However, as the brainstorming session includes individual ideas and proposals, it was found preferable to conduct the idea generation stage on an individual basis.

*Time Allocation:* The limit was found enough, which was approximately 15-20 minutes for a design problem, card or strategy.

*Use of Cards:* Various uses of cards were tried out such as single or multiple use and free or random selection. Cards were found more suitable in a free use mode as both single or spread, where they were related or combined on occasion. Random assignment of cards was found compelling and limiting, therefore was eliminated from the exercise.

Through the received feedback, an additional ‘analysis session’ was placed into the exercise outline between the two sessions of presentation and ideation. The hands-on group analysis included a critical discussion on nature and human packages and the examination of the design brief. Thus, the workshop format was finalised into the current format that was used in the field study. Finally, the general observations and suggestions were considered to improve the overall process of conducting the exercise.

### 3.3.2.2. Workshop Outline and Format

The card deck was formed into a one day workshop exercise to be evaluated within the ideation stage. The revised workshop format mainly consisted of three phases as follows (the workshop brief is included in the Appendix D):

- Presentation with background and examples on nature inspired design, design paradigms and packaging; the design brief and the introduction of the NDP Card Deck
- Hands-on group analysis of natural and manmade packages
- Individual design process in two sessions, first without using the card deck, and then designing with utilising the deck.

Firstly, an initial presentation introduces the concepts of nature inspired design, design paradigms and packaging design with exemplifying the interrelations between. After the presentation, an analysis phase follows where nature and product packages are examined from a critical perspective. Exercise then continues with the design phase that can be held as multiple sessions depending on the brief.

Two consecutive ideation sessions are performed; the first session is a regular process of idea generation whereas the second session is supported with the use of NDP Card Deck tool. Each idea generation session took about an hour and consisted of three packaging design problems – dragee, toothpaste and matchstick packaging (see section 3.3.2.4). Therefore approximately 15-20 minutes was given for each design problem. The participants sketched design ideas and the outcomes were submitted at the end of each session. After the exercise sessions, an evaluation survey was provided to collect participants' assessments. The next section presents details on the conveyed presentation.

### 3.3.2.3. Preparation of the Presentation

For the beginning of the exercise an informational phase was needed, since the target audience did not have any background in biology. Thus, a presentation was an

essential step in communicating the main concept and supporting the practical session that followed. Referring to the literature and with the use of preliminary survey findings, the presentation on designing with nature inspired paradigms was prepared and delivered.

The presentation has three major subjects; nature inspired design with an emphasis on the biomimicry approach and its tools, packaging design with its considerations and the design paradigms concept. All subtopics were supported with examples and elaborately selected visuals, as they convey the meaning in a quickly graspable way. Following this general framework, an overview of the workshop stages was conveyed along with the design brief. The outline of the presentation is as follows:

- Nature inspired design, definition and brief background
- The biomimicry approach, its levels and tools
- Packaging design, definition, considerations and recent focuses
- Nature packages
- Packaging design examples that utilise these focuses and approaches
- Design paradigms, definition, their use in products and nature
- The exercise stages with the design brief
- The introduction of the NDP Card Deck and its use in design process


Figure 3.10 – An exemplary slide from the presentation on nature design paradigms in packaging design

An exemplary slide is presented in Figure 3.10 that shows how nature paradigms correspond to the design of packaging (full presentation is included in Appendix E). In a similar way, examples on the relation between paradigms from nature and objects, and applied cases from industry were given. Through these samples, paradigms were identified with their functions and strategies to give insights on the notion.

Prior to the introduction of the card deck, the approach was explained with the thinking behind, consequently the NDP Card Deck tool was introduced as a method that is derived from this approach. Therefore, it was aimed to make designers easily relate to the given tool. The next section explains the process of specifying the design problems.

#### 3.3.2.4. Specifying the Brief

The design brief to be worked on through the exercise process is specified with various concerns in mind. However, the general focuses were the diversity and space for improvement within the concepts. Within the selection process, packages were evaluated with regard to the relationship of the package and its contents, the context of use, the physical state of the contained items. The scenario of the package was also considered in terms of where it is located or carried, how it is opened/closed and what kind of a lifecycle does it have – e.g. what happens after its disposal.

Lastly, packages from different areas such as food and hygiene were reviewed to bring varied dimensions and strategies to ideation process. Three packaging problems were selected in accordance with the mentioned features for the brief in relation with the projected workshop schedule. Consequently, the brief consisted of the following:

- A dragee package
- A toothpaste package
- A matchstick package

Specified packages include a range of considerations, such as reopening and closing several times, multiple similar or dissimilar items contained, form and function relationship and the use and disposal of items. In this sense, conventional packages were especially seen as opportunities for innovation.

### 3.3.3. Conducting the Workshop

As mentioned earlier, the nature inspired design paradigms exercise and the card deck were updated and the workshop format was finalised with the feedback from the pilot session. The workshop was conducted within the second year studio, the outcomes were collected and the exercise was evaluated with the participants.

#### 3.3.3.1. Population and Sampling

The exercise was carried out among the second year industrial design students at METU. The sample group was preferred as they were not introduced to the nature inspired design approach, yet performed projects related to packaging design. 40 out of 41 students participated in the workshop and submitted outcomes and the questionnaire.

#### 3.3.3.2. The Exercise Process

Starting with an initial presentation, the workshop utilised the proposed approach through the use of the NDP Card Deck. The participants brainstormed and generated ideas on the given brief within several sessions. Finally, an overall evaluation was made on the exercise and its phases. Both the researcher and the supervisor were present at the workshop process as facilitators to provide information and critique throughout the sessions.

The presentation and the analysis parts were carried out as an interactive lecture with questions, answers and comments, to engage the participants in the process. Instead

of conveying only information, the approach was communicated by through provoking participants to think as ‘how would have nature packaged that?’. At the end of the presentation, the brief that included three design problems was presented with general information on the remaining phases as well. Explanation on the challenges also provided to help participants in framing problems through various contexts.

Samples of nature and product packaging brought by the participants and the researcher were laid out for exploration. Then, a critical discussion was made on packages, their physical qualities and purpose of use, employed strategies and paradigms. Packages were also evaluated in terms of their context, scenario use and disposal. Nature and human packages were investigated in terms of their sustainability concerns and not surprisingly, nature packages were found superior regarding this issue.

Analysis section included the evaluation of natural packages such as eggs, onion, banana, garlic, pine cone etc., and product packages like chewing gum package, various candy and chocolate packages, as well as the matchstick and toothpaste packs. Following this preparatory session, the workshop continued with the practical design phase. As mentioned earlier in the integration part, the design ideation phase was conducted in two sessions, firstly without the use of cards, and then with using the cards. The NDP Card Deck prototypes were distributed to each participant in a physical print out form.

The sessions included three design challenges to generate solutions for and the participants sketched their initial ideas in this phase. Critique and support was provided in every step of the exercise to lead the participants in progressing through ideas, as they were newly introduced to both the concepts and the exercise method. Throughout the practical session, it was emphasised that the card deck is a tool for inspiration and stimulation, rather than a library of strategies to simply apply or add to design ideas. Therefore, free flow of ideas and sketches was encouraged with the card deck acting as a starting point.

### 3.3.3.3. Outcomes and Their Analysis

The idea sketches were collected at the end of each session. The participants were to submit a total of 6 outcomes, yet there were participants who were incapable of fulfilling this number. An example from the exercise outcomes is presented in Figure 3.11.

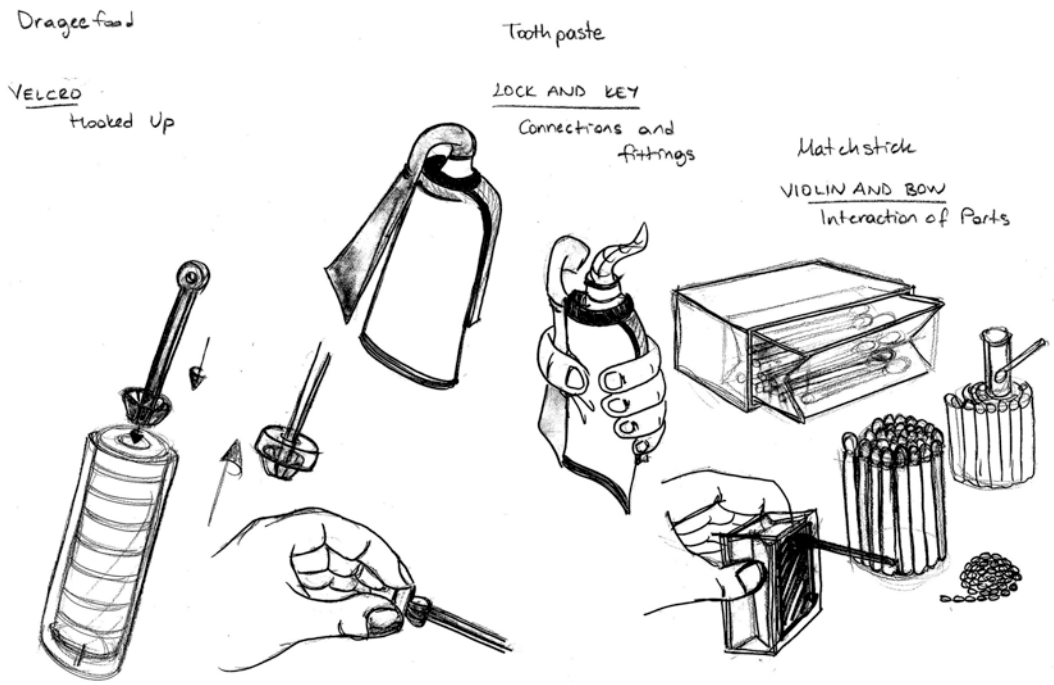



Figure 3.11 – An Example of the Exercise Outcomes

Although the participants had difficulties in submitting three outcomes for each session, they were able to submit at least one idea for each phase. Thus, a quantity-based analysis was made in terms of the number of ideas and their increase/decrease between sessions. Additionally, case studies enabled to gain insights on the utilisation of the tool and the thinking process of the participants, in combination with the evaluations. The implications were discussed through these analyses and inferences were made.

#### 3.3.3.4. Evaluation of the Workshop Exercise

The final input for the research was the feedback from the participants in order to evaluate the tool and the exercise process. For the collection and analysis of the data, the questionnaire method was employed with thematic coding analysis. This section explains the research methods and their use in this study.

##### 3.3.3.4.1. Data Collection: Questionnaire

Survey is a preferable data collection method in research as it allows access to respondents' assessments on a subject in a practical manner. A questionnaire in form of a written document to be completed by respondents was prepared for the evaluation stage of the study and delivered to the participants at the end of the exercise. The questionnaire consisted of open-ended questions that enable access to more information and insights, rather than limiting participants' answers to pre-set answers (CSU, n.d.). Within the survey, biased and leading questions were avoided and instead, participants were encouraged to reflect upon their experiences in a free manner.

The questionnaire was structured in mainly two parts that focus on the conduct of the exercise and the personal reflection on the approach. The first section evaluates the workshop process, the card deck and its appropriation, where the latter one concentrates on the nature-paradigms-design notions and the individual assessment on the exercise.

The structure of the survey was elaborated within the pilot workshop interviews conducted with the focus group. Questions were revised, added and the order was rearranged. The final survey questions are presented in Table 3.3 and the original spread is included in Appendix F.

Table 3.3 – The Evaluation Survey Questions

**1 - Workshop Process**

Q.1. Was the workshop process clear to you? Was the brief explanatory enough? Was the Card Deck's placement/utilisation in design process clear?

Q.2. How would you evaluate the Presentation in workshop process? What points were influential/interesting? How did it influence the design process?

Q.3. How do you think of the group conduct of the analysis phase followed by an individual conduct of the idea generation phase affected the ideation sessions?

Q.4. What was your approach towards the design brief? Did you ideate on the concept as a whole, or did you develop specific parts of the packages?

Q.5. Did you find the allocated time for each design sufficient? Were you comfortable in developing ideas within this time limit?

**2 - The NDP Card Deck**

Q.6. What do you think about the NDP Card Deck's design? Can you elaborate on;

- Images, keywords and their relation to paradigms and strategies,
- The way you utilised the cards in your process,
- The side and parts you used most?

Q.7. On the ways you made use of the cards;

- Did you use more than one paradigm in a single idea? Please exemplify.
- Did you make use of the cards independent from its context with different perspectives / features / qualities? Please exemplify.
- In which dimensions did you ideate (i.e. form, function, materials etc.)?

Q.8. Do you think the language of the cards (in English, not native) had effects (positive/negative) on your design process?

Q.9. How would you evaluate the structure of the cards? Were you comfortable in progressing through the cards? Would you prefer to have categories?

Table 3.3 – The Evaluation Survey Questions (continued)

| |
|---|
| **3 - Nature Inspired Design and Design Paradigms** |
| Q.10. How would you evaluate the Design Paradigms approach? Were the concept and introduced paradigms new or familiar? Would you consider using this design approach in the future? |
| Q.11. Did the exercise have an influence on your perception on nature, if so, in what way? Would you consider referring to nature in your future studies? |
| Q.12. How influential was the exercise for you in associating nature, paradigms and design? Were you aware of such a relationship and what would be your attitude towards the subject in future? |
| **4 - Personal Assessments** |
| Q.13. How would you describe and evaluate the NDP Card Deck Exercise, could you elaborate on the process? What do you think of it as a design tool and how did it affect your design ideation process? |
| Q.14. What was the aim of this exercise in your opinion? Do you think you have achieved this aim? Could you explain? |
| Q.15. How would you evaluate your performance and the design ideas you developed through the exercise? Would you consider improving these concepts further for use? |
| Q.16. Were there any difficulties you faced in the workshop process? Could you make suggestions on improving this exercise? |
| Q.17. Comments and further thoughts. |

The evaluation session was about 30 minutes long and took place right after the design ideation, which made it easy for participants to express their remarks on the exercise without the difficulty of recalling. A consent form was also provided prior to the exercise for the use of outcomes and questionnaire results (included in Appendix G).

### 3.3.3.4.2. Data Analysis: Thematic Coding and Analysis

Thematic coding and analysis is a data analysis method that aims to capture important concepts in the data set by summarizing and reconstructing the qualitative data (Ayres, 2008). The method uses codes and categories as tools for identifying patterns of words, phrases and concepts. In specifying these codes, either inductive or deductive analysis approaches are followed according to the qualitative or quantitative nature of the research. The inductive process is preferred in this study, as it allows an in depth analysis of data and interprets the contextual meaning, instead of using pre-set concepts as in deductive approach. Thus, categories were defined in line with the insights from the data, the exercise process and outcomes, and the evaluation questionnaire. Table 3.4 shows the outline of categories.

Table 3.4 – The Categories for the Analysis of the Primary Research

| | Sub-categories | Category Description |
|---|---|---|
| **Nature Design Paradigms Card Deck Exercise** | Presentation | Integration of the NDP Card Deck Exercise into the idea generation stage in design process |
| | Design Brief | |
| | Conduct of Exercise | |
| **Appropriation of the Card Deck** | Design of the Cards | Integration of the NDP Card Deck into the design process |
| | Use of the Cards | |
| **Nature, Paradigms and Design** | Nature | Influence of the approach on students' awareness of nature, paradigms and design relationship |
| | Paradigms | |
| | Relation with Design | |
| **Personal Assessment** | Implications of Approach | Implications of the approach on students and insights into further development of the exercise |
| | Perceived Aim | |
| | Diffulties & Suggestions | |
| | Future Use | |

The questionnaire results were analysed in accordance with these categories and sub-categories. Examining the information through generated themes, the method reorganises the data set in a useful manner without discarding the intricacies of meaning (Guest, MacQueen & Namey, 2012). The outcomes of the exercise were also analysed using these approaches and the participants were grouped according to several categories, such as their attitude towards the exercise, their performance and outcomes. Using these techniques, the analysed data results were cross-referenced with the assessments and the outcomes. As a result, conclusions and inferences were made, which will be presented in the next chapter.

### 3.3.4. Limitations of the Study

The one day conduct of the exercise presented limitations, yet it was preferred for practical purposes. However, as the program was intense and demanding, time allocation and duration posed difficulties for the process. The questionnaire results also point to the time limitation as the majority of participants agree that the task required more time. The exercise may have provided better results if the time limit would be longer, since then it would be easier to incorporate the approach to the design process.

In terms the participants, the second year students were not experienced enough in the design process, yet this was the first time they were introduced to a fast paced brainstorming and idea development sessions. Also the repetition in the stages made it difficult to find new ideas for the second session for some participants, whereas it is also possible that another group was warmed up and performed better since they built upon in the second session. Increase or decrease in productivity, therefore, may be due to these factors as well.

As a result, it was a challenging process, yet the majority of the participants were pleased to participate in the exercise. In addition, the participants were comfortable as the workshop was an educational process and the outcomes were not evaluated as a part of studio performance.

From perspective of Biomimicry, approaches follow 3-4 days programs including an allocated time for a nature walk. Since the nature design paradigms deck acts as a tool that categorises the design strategies and their origins in nature, the use of online resources or databases like asknature.org or nature walk were not required. However, the course of the exercise followed a reductionist approach as the outcomes reflect the level of inspiration on a form and function basis, without the use of systems and processes.

In this chapter, the research process and the data collection and analysis methods utilised in the study were presented with their appropriation. The next chapter focuses on the outcomes of the research.

# CHAPTER 4

# RESEARCH

This chapter presents an in depth analysis and results of the study, the preliminary study and the primary research in particular. The findings include the conclusions from the research, the student cases and the evaluation of the supervisor. The chapter wraps up with general conclusions and insights of the research.

## 4.1. Preliminary Study and its Outcomes

In line with the aim of the research, a survey was conducted in order to evaluate the awareness of design students on nature inspired design and design paradigms. The survey was conducted among 39 students out of 41 second year students at METU ID Department. Questions from 1 to 4 were related to nature inspired design and questions 5 and 6 were about paradigm use in design. The answers and the results are as follows.

### 4.1.1. Nature Inspired Design

**Question 1. Do you inspire from nature in your design process? If so, could you exemplify?**

The first question aims assess the awareness and conception of nature in relation with design and understand the ways participants are inspired by nature. 35 participants out of 39 answered positive to this question. The responses were distributed within the following categories (Figure 4.1):


Figure 4.1 – Inspiring from Nature in Design Process

A major part of the participants, 16 of them, were mainly inspired from nature on aesthetics basis. Referring back to basic design course studies, participants gave examples from the first year bathroom accessories project. Their inspirations involved honeycomb structures, DNA, sea waves, stones, array of leaves and pinecone. In addition, water drop, tulip, snail and diamond forms were among the examples that were mentioned. This is generally a form-oriented approach, where the relation between the appearance and the function of the design is often disregarded.

Five participants were inspired from the solutions in nature in terms of working principles, forms or functions, and were essentially focused on the strategies provided by nature. The examples include the investigation of opening and closing structure of stomas in leaves for a clothespin and the push-open structure of snapdragon flower for opening of a package design. This category is more efficiency based in comparison with the first one and is closer to the biomimicry approach.

There were another group of participants, who provided examples that are irrelevant to the concept. Reported in the answers by seven participants, responses point to a misinterpretation of the concept, as in the example of inspiring from the chicken's head in an egg packaging design. This group shows that there are misconceptions about the nature inspiration approach among design students. In addition to these, two participants mentioned that they tried to get inspired by the nature, yet are unsure of the results. This group constitutes a 'tried but failed' category, as the participants think they can't use nature inspiration properly. The findings indicate a

lack of knowledge on the subject, as with the previous category. Seven participants stated they do observe the nature for design inspiration, yet did not refer to an example. Only four participants replied negative and expressed that they have not got inspired from nature in their process so far.

These categories and analyses raise some issues regarding nature inspiration among design students. Results indicate that observing nature is a common approach embraced by design students and the comments show that the studio instructors lead them to look at nature. Yet, 'inspiring from nature for design' is a vague concept and can be misinterpreted by designer candidates easily. It was seen that the second year design students are mainly influenced by nature on an aesthetics based and form-oriented level. However, they lack knowledge on the method, its dimension and applications. There are even participants who are unconfident about their use of the approach, as a result of these reasons. In short, answers to Question 1 reveal that though it is a widespread practice, the concept of 'nature inspiration for design' is mostly (23 out of 39 participants) lacking or unclear among the second year design students.

As the responses were analysed to investigate the conception of the approach, verbal connotations were collected through the words and phrases within the comments. The participants' expressions on their methods of inspiring from nature were decoded in particular to obtain the underlying perception on the relation of nature and design.

| | | | |
|---|---|---|---|
| Adapt | Use | Benefit | Inspire |
| Bring | Create | Shed Light | Apply |
| Observe | Transfer | Take Reference | Solve Problems |
| Compare | Evaluate | Analyse | Develop |

Figure 4.2 – The words participants used to refer to nature inspired design

Figure 4.2 presents the verbs the participants related to nature inspired design. As the figure illustrates, the actions range from imitating nature to adding features to

designs. Most of the words are commonly used terms in product design process and nature inspired design process as well. These findings were useful in the conduct of the exercise where the methods of inspiring from nature were explained.

**Question 2. Do you know of an approach/method that is focused on nature inspired design as a discipline? If so, please explain.**

In order to investigate the knowledge on the methods of nature inspiration for design processes, the second question inquires the familiarity of concepts as biomimicry, bionics or biomimetics. 12 out of 39 participants mentioned the term 'Biomimicry', while the remaining 27 participants could not provide an answer. The definitions of biomimicry made by the participants are analysed in order to analyse their understanding of the concept. Thus, answers were classified under the four general statements presented in Figure 4.3.


Figure 4.3 – Descriptions of Biomimicry by the Participants

'Inspiring from/imitating nature for design process' provides a general description of the biomimicry approach. 'Analysing and using the principles of nature for solving design problems' is a more refined statement that refers to the aim and the process of the method. 'Nature holds the best solutions for design' is an opinion rather than an explanation of the concept. And 'Form follows function in both nature and design' is a too broad notion and is somewhat unrelated/does not present the main idea of the concept. Consequently, 10 participants out of 12 were informed of the biomimicry approach and could define the approach in a correct/associated manner. One student referred to the nature as having the best solutions and one student had an unspecific and irrelevant remark that form follows function both in nature and design.

**Question 3. Could you name any examples of nature inspired design?**

The answers to nature inspired designs and products question include some common sense examples of objects and products such as vehicles like plane, helicopter and submarine, hydrophobic materials imitating plant leaves, sharkskin inspired swimwear, and clamshell packages. In addition to these, well known applications of biomimicry were mentioned as Velcro, Boxfish Car, Bullet Train and Gecko. Examples are visualised in Figure 4.4.

| | | | |
|---|---|---|---|
| Clamshell Package | Submarine | Helicopter | Works by da Vinci |
| VW Beetle | Pliers like claws | Juicy Salif | Hexagon Structures |
| Boxfish Car | Velcro | Bullet Train | Works by Lovegrove |
| Sharkskin inspired swimware | | Planes from Flying Creatures | |

Figure 4.4 – Examples of Nature Inspired Design provided by the participants

As the range of examples implies, participants refer to many aspects of nature inspired design in regard with the proportional studies, natural impression, organic design and biomimicry.

**Question 4. Please check the words you find relevant to nature inspired design.**

The results to the question are visualised in Figure 4.5 and Figure 4.6.

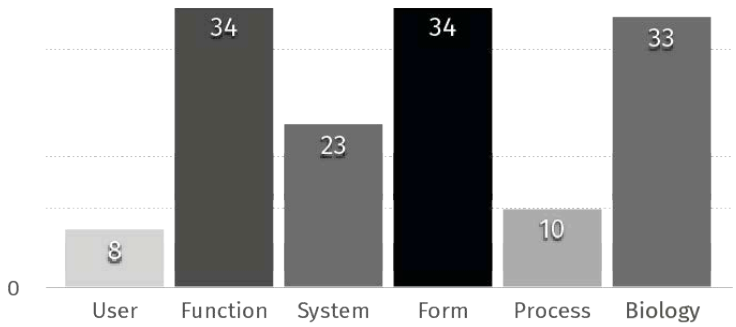



Figure 4.5 – Answers to Question 4, Section 1

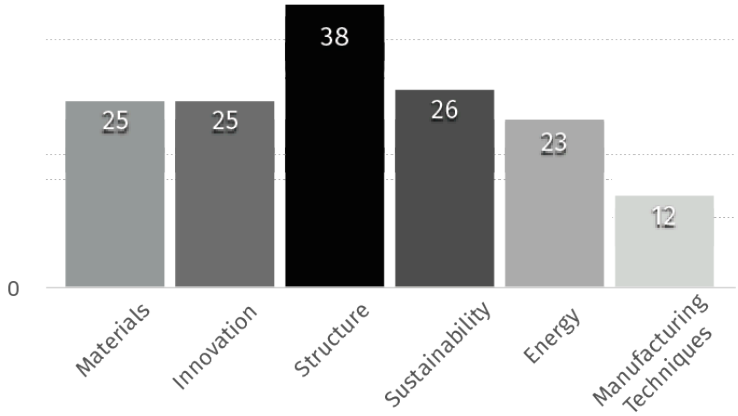



Figure 4.6 – Answers to Question 4, Section 2

Results show that a majority of participants perceive nature inspired design as prominently related to form, function and structure. Following these, system, material, innovation, energy and sustainability were recognised as associated concepts, while manufacturing techniques, process and user were found least connected according to survey findings.

### 4.1.2. Design Paradigms

Questions 5 and 6 aimed to assess the abilities of metaphorical thinking and alternative creation with paradigms in design process. The results present a diverse range of paradigms and accompanying techniques for expression.

**Question 5. A number of ways can be utilised to make an object open/closed. For example, a hinge or a snap fit detail can be employed. What else can be applied to achieve that aim?**

Each student was able to generate at least one solution for open/closed problem. Participants provided 26 unique paradigms that include mainly form, function/mechanism and material strategies. Ideas span from sliding mechanism to magnets and expansion. A full list is available in Figure 4.7 with the number of generated paradigms.

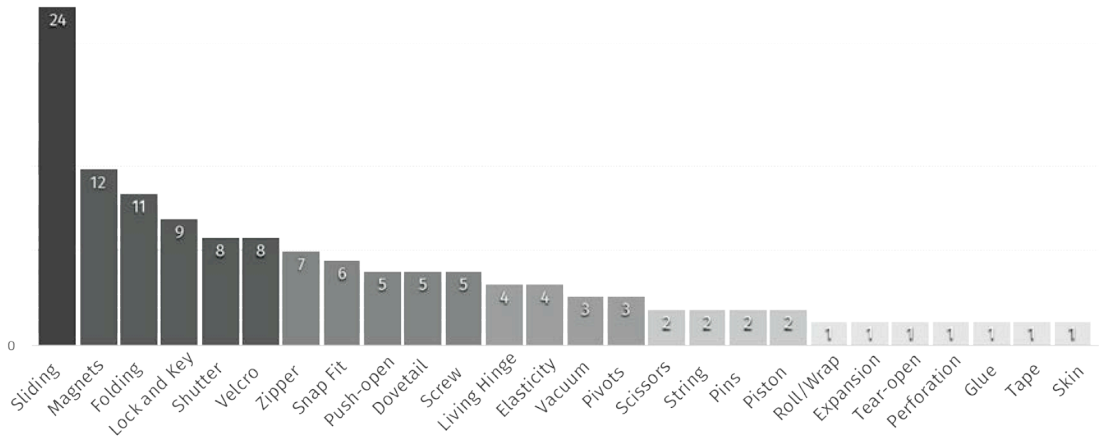



Figure 4.7 – The paradigms provided by the participants for the open/closed problem

**Question 6. An object can change shape and size through use of bellows. Which techniques can you think of to be used in order to have objects change its shape/size?**

All participants were able to answer this question. The total number of variations is 21, yet similar strategies to the prior question exist. Paradigms range across telescopic mechanism to inflation and centrifugal force. The provided examples are presented in Figure 4.8.

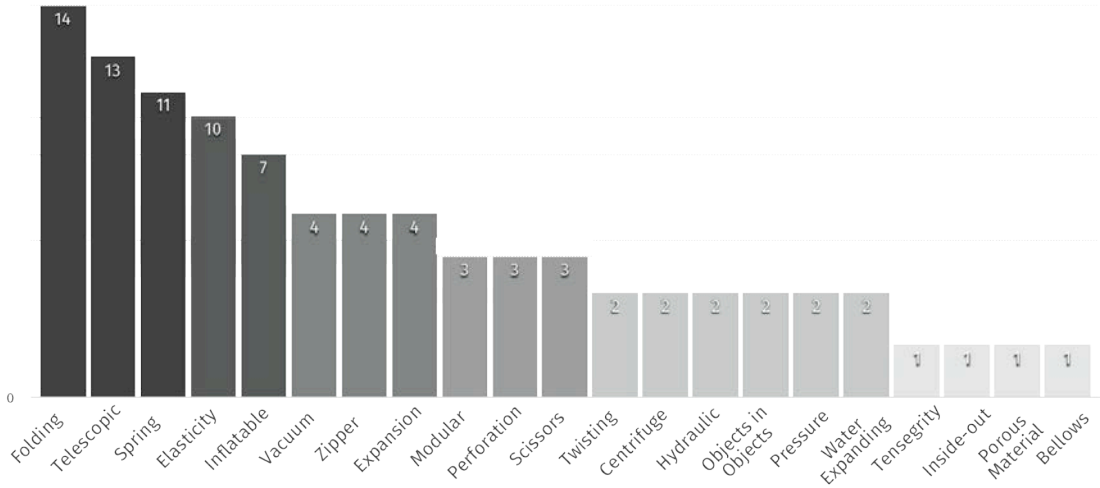



Figure 4.8 – The paradigms provided by the participants for the change shape/size problem

Through these questions related to the ability of using paradigms in design, it was observed that the frequencies of the generated strategies changed dramatically. The participants were encouraged to suggest as many paradigms as they could. The most utilised strategies were probably the ones they could easily think of and relate to, such as ‘folding’ and ‘sliding’. There were also less frequent paradigms that defined the extreme points, including ‘centrifuge’ and ‘tensegrity’. However, the least mentioned strategies included some common paradigms found in everyday life as well, such as ‘glue’ and ‘tape’. The number of generated paradigms for a question changed between 1 to 11, yet the average was about 3 strategies.

### 4.1.3. Inferences from the Preliminary Study Outcomes

The preliminary study was helpful in gaining insights on participants’ conception and approach on nature and design relationship. It also enabled to make inferences on their knowledge level and observe their solutions to problems. Main conclusions of the preliminary study are as follows:

*Lack of Knowledge on the Approach:* Nature as an inspiration source for design is widely acknowledged among design students with nearly 90 percent of them stated that they inspired from nature in their design process. Additionally, a group of participants mentioned the biomimicry approach as a nature inspired practice for design. This awareness might be due to the suggestions by instructors, however it is apparent that students lack knowledge on the methods and its applications. The provided examples show that majorly a form-oriented approach is followed in inspiring from nature, yet there are misinterpretations and irrelevant practices as well.

*Dimensions of Nature Inspired Design:* The participants referred to several aspects within nature inspired design as organic design, nature studies as proportion, naturalism or natural impressions on design and the biomimicry approach. This indicates they primarily perceive the nature useful in terms of form, function and structure and are unaware of the solutions it presents regarding ecosystems, processes, materials etc.

*Paradigms Thinking:* The participants were comfortable in generating variations using paradigms without being provided with any detailed explanation on the subject. Metaphors and strategies were employed in the creation of alternative solutions, which ranged from mechanisms to various materials. Furthermore, there was a correlation between the use of metaphors and the number of ideas developed. The participants who were able to develop a number of variations were likely to describe the paradigms with using examples of existing products, mechanisms or concepts. 7 out of 10 participants that used the phrase 'as in' to suggest a similar principle were able to generate more than three ideas. This may point to the ability to perceive and use paradigms in design through metaphors and analogies.

The findings provided inputs for the preparation of the exercise, as well as the presentation and cards. The next section explains the course of the primary research and its results.

### 4.2. Primary Research

The primary research was conducted within a workshop exercise that utilised the NDP Card Deck tool to assess its effects to the design process. This chapter presents the process, its outcomes and results in detail.

#### 4.2.1. The Workshop Exercise

As mentioned in the previous chapter, the workshop exercise consisted of a presentation, a group analysis session for packages and design ideations sessions with and without employing the card deck.

For the preliminary study results pointed to the lack of knowledge in the subject, the participants were provided with the information on the nature inspired concept, its origins, dimension, examples and its relation to design and paradigms. They were also encouraged to inspire from the strategies on various levels – e.g. materials, systems – to achieve improvements, instead of being influenced only in a form-

based manner. The following group analysis session enabled the participants to analyse the existing products with the paradigms approach and to define context and problems relating the production, use and disposal of the packages. The next part included the idea generation phase and in the final part, they evaluated the exercise through the questionnaire.

The analysis of the exercise outcomes and the questionnaire results will be discussed in detail in the upcoming sections. Nonetheless, a general overview of the ideation process regarding the generated ideas and the participants' assessments allowed conveying the workshop process from a practical perspective. To start with, the number of ideas generated in the first and the second sessions were marked for each student. This enabled to draw a quantitative outline of the exercise and to group the participants in accordance with their performances within the two sessions.

The number of ideas fluctuated between the participants, yet a large part of them (27 out of 40) were able to provide the required number of ideas at least in one of the sessions (Figure 4.9). Each student was able to submit an idea within each session and regarding the number of ideas, an increase was observed in 11 students (Group a), a decrease occurred in 8 students (Group c) and 21 students (Group b) had an unchanged number of concepts within the two sessions.

Subsequently, this classification of the quantity of ideas was cross-referenced with the evaluation results and the students' assessments on the exercise process were combined into this data. Answers to the survey pointed out that 10 students (Group 1) had a positive feeling towards their performances and exercise outcomes, whereas 19 students (Group 2) had a neutral feeling and 11 students (Group 3) had a negative feeling. As a result, the participants were divided into three categories according to their positive, neutral or negative stance.

The final grouping included nine groups presented in Table 4.1.

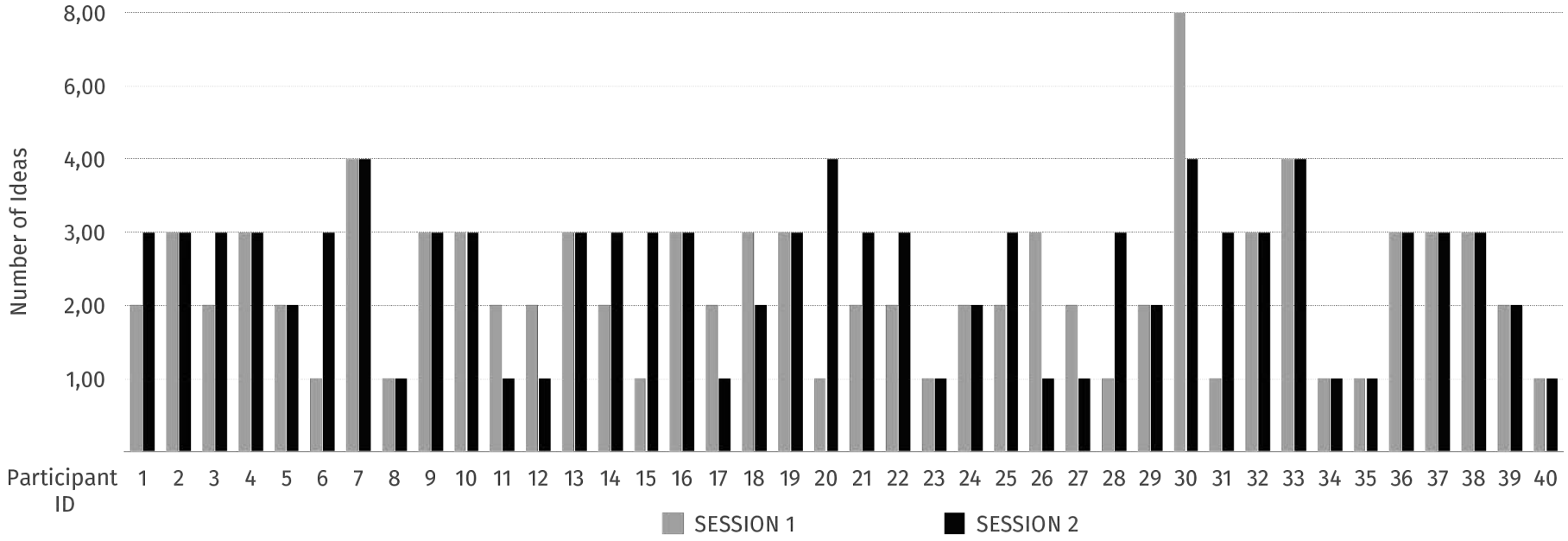



Figure 4.9 – Number of Ideas generated by Participants in Session 1 and Session 2

Table 4.1 – The grouping of the students according to their assessments on their performances in relation to the change in the number of generated ideas

| | | Students' Assessments on Their Performances | | | |
|---|---|---|---|---|---|
| | Groups | 1 POSITIVE | 2 NEUTRAL | 3 NEGATIVE | Total |
| Change in the Number of Ideas | a- INCREASE | 3 Students | 5 Students | 3 Students | 11 Students |
| | b- FIXED | 4 Students | 12 Students | 5 Students | 21 Students |
| | c- DECREASE | 3 Students | 2 Students | 3 Students | 8 Students |
| | Total | 10 Students | 19 Students | 11 Students | |

Although there are several aspects and motivations behind these differences, the grouping of the participants makes it easier to analyse their reasons in accordance with specific criteria and draw conclusions from those relations. The groups will be referred to in the section that analyses the exercise outcomes through student cases. The next section presents the results and findings of the evaluation questionnaire.

### 4.2.2. Evaluation of the Exercise

In this section, the survey results that include the participants' assessments and comments on the exercise will be presented. The findings were grouped according to the categories specified for the research and the evaluations were analysed. Finally, general conclusions on the exercise results were discussed. The questionnaire consisted of two parts mainly focusing on the conduct of the exercise and the personal reflection on the approach. The first section evaluates the workshop process, the card deck and its appropriation, where the latter one concentrates on the nature-paradigms-design notions and the individual assessment on the exercise.

#### 4.2.2.1. The Workshop Process

As the exercise was a one-day intense program, a large part of the participants stated they had difficulties with time limitation. However the process was described generally as learning and fun. Evaluation of the workshop process by participants

were analysed within the exercise outline and the results will be presented in this section.

#### 4.2.2.1.1. The Presentation

The presentation included in design process was perceived as interesting and informative in general and especially the examples of nature and manmade packages were found effective in communicating the approach. Being essential for the design stage, the presentation introduced the basics of the concept and prepared the ground for the practice session. Besides these purposes, comments reveal that the presentation helped participants in a number of ways; *they were introduced to the nature and design relationship, they became aware of the design paradigms concept, and finally they have learned more about the design process, particularly packaging design and its considerations.*

Participants indicated that they found the inspection of nature from a design point of view intriguing and the introduction of this approach led them to acquire a new perspective on the subject. Nature inspired design examples were important to illustrate ways to observe and employ nature inspirations, since the workshop participants were new to the subject. On the other hand, the participants realised the paradigms approach, with which they were familiar from their previous experiences. Evaluation results illustrate that presentation assisted them in inspiring from nature and paradigms in the exercise process.

#### 4.2.2.1.2. The Design Brief

The participants found the design brief and the instructions clear, and expressed that the placement and utilisation of the card deck in design process was comprehensible. Comments refer to the variety in brief selection in an approving manner, stating that it was helpful to think in a wide range of problems and solutions, rather than being stuck in one subject. It was stated that this enabled participants to realise the different considerations raised by each given subject. Assessments also point to the

multiple items thinking in one session; according to participants it was a new and challenging design process, which led them to experience a different design process.

**Dimensions and Considerations**

The approaches of participants in terms of responding to the brief were aspects to be inquired among with the considered dimensions. Concerning the ideas generated, the design problems were both examined as a whole and in parts. This was an emphasised point in the early discussion with an aim to support the variety of ideas within diverse possibilities of packages. The participants evaluated the packaging problems and proposed concepts both as overall developed ideas or improvements of parts, features and functions. The latter approach was focused mainly on the usage, i.e. opening and dispensing, and aims to generate more user friendly packaging designs. To illustrate, design ideas regarding the toothpaste package were mostly concentrated on the opening lid, rather than generating a brand new packaging design. This may be due to the functional concerns of the majority of participants over variation through forms, as seen through the results of dimensions.

The strategies and paradigms were employed within several dimensions such as form, function, materials etc. However, the results of both survey and the outcomes point to the function as a more prominent consideration that was followed by ‘form’ and ‘material’ factors in general. There are a few participants who considered both the form and the function dimensions and tried to use several paradigms at once. This result indicates to a change in the participants’ approach to nature inspired design.

As the preliminary research findings revealed, the participants had studied nature in a form based manner in their previous works, yet they emphasised both form and function dimensions in the survey questions. However, the exercise outcomes show that the participants were inclined to investigate the function dimension instead of form qualities. This may point to the utility aspect that is provided by the card deck, as it includes a handful of knowledge rather than suggesting merely visual inspiration.

#### 4.2.2.1.3. Group Analysis and Individual Conduct

The exercise was conducted as group work in analysis session and as individual work in ideation session due to the findings of the pilot workshop and suggestions from previous studies that suggest a group work in analysis phase to provide different perspectives and thoughts from participants and facilitators. Therefore, a group analysis on nature and manmade packaging with the paradigms and strategies utilised was held prior to idea generation stage.

The majority of the participants (29 out of 40) evaluated this approach as positive and indicated that it was beneficial to have a discussion on the concepts and defined brief context beforehand the design stage. According to comments, this enabled them to learn about other people's thoughts and perspectives and to observe the variety and range of approaches. They also regarded the following ideation stage favourable in individual form, since they were able to synthesise their thoughts and associate the concepts in order to develop their own ideas.

Nonetheless, there were few participants who prefer the exercise in form of a group work (7 out of 40) or suggest having at least one brief as a collaborative process (4 out of 40). For the aims and structure of this study, individual design ideas were preferable as it is easier to measure and compare the results.

### 4.2.2.2. The NDP Card Deck

The participants' evaluation on the design and the utilisation of the card deck was positive in general. Within the survey, participants evaluated the design and their appropriation of the deck. The results are presented in the following sections.

#### 4.2.2.2.1. Design and Content

The deck's design in terms of its physical qualities and the contents was found adequate and referred to as 'simple, clear and comprehensible'. The visuals and the

keywords were also described as helpful by being explanatory and concise, whereas the images were ascribed as influential and captivating.

### The Language of the Cards

The NDP Card Deck was prepared in English as the education and the classes are carried out in English at METU. Regarding the language of cards, about half of the participants stated that it would be preferable to have the cards in their native language. The remaining half, however, thinks that language did not pose any negative effects; furthermore there are few participants that indicated it was useful for a technical vocabulary. Survey results are visualised in graph Figure 4.10.


Figure 4.10 – The Effects of the Language of the Cards

As seen on the graph, seven participants mentioned that it had a negative effect to have the deck in a non-native language and nine participants stated they had difficulties in some keywords, yet managed to make sense of them. A group of seven participants also expressed that they would prefer to have the deck in Turkish, without referring to any negative effect. On the other hand, 12 participants stated that the language did not pose any difficulties, while four participants found it beneficial for learning new jargon words.

### Structure of the Cards

The independent structure of cards was found convenient in general. The majority of participants (34 students) expressed that they were comfortable in associating cards in this way as they think a categorisation might have led to limitation, complexity

and bias. There are a few participants (six students), however, that prefer the deck in groups or categories.

The card deck was prepared as individual yet interrelated paradigms, thus the separate structure has connectivity within the concepts on occasion. As explained earlier, the 'related terms' section aims to show these links between strategies for participants to further investigate associated principles. A comment refers to this issue and hints a digital extension or interface, where participants can interact with cards in various levels. As Student 16 suggests;

> 'It is nice to have the cards as physical objects, better than a screen. However, I would also like to have a map, where you can browse the cards by choosing an aim, that way I would have seen all the cards related to, lets say protection aim.'

This leads to a point that was indicated in literature for future considerations. In their work, Merritt and Wölfel (2013) suggest digital augmentation to show similarities between individual cards and underlines that digital technologies can enable visualisation of connections virtually and present additional information.

Therefore, the use of a digital platform; a website, application or similar would be helpful to classify and select the cards according to different criteria. Regarding the NDP Card Deck, the 'related terms' section could be improved further to have a visual map of links for future improvements.

#### 4.2.2.2.2. Appropriation

##### Use Pattern of the Card Deck

The participants' assessments on use of the card deck revealed a pattern on the utilisation of the deck. The process was explored in four steps including 'Overview', 'Elaborate', 'Inspire' and 'Implement' that was visualised in Figure 4.11.

As exposed in the graph, the card deck's use begins with the 'Overview' of the cards; where cards and paradigms are examined to gain insights on the concepts. The participants browsed through the cards or laid out the deck as a spread to take a look at the items. The comments indicate that the cards that are found inspirational were selected in accordance with the brief. Some participants stated that generation of ideas started from the selection of the paradigms: 'Ideas sparked in my mind just as I was looking at the pictures'. Thus, it can be asserted that the deck stimulates ideas from the beginning of its introduction in some cases.

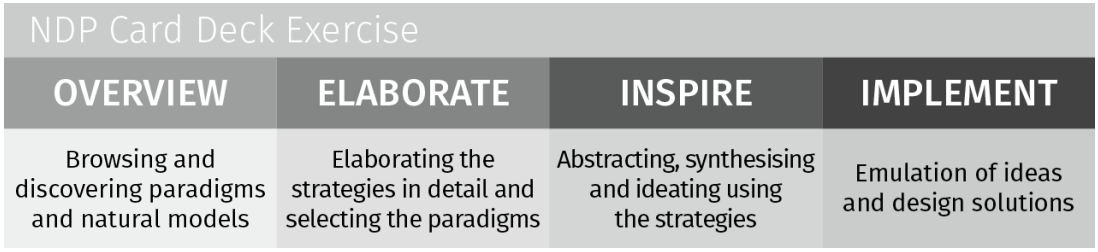



Figure 4.11 – The Utilisation of the NDP Card Deck in the Design Process

The next is the elaboration phase and the selected cards are studied in detail within this part. Through the exercise, the tendency was to check the images first, and then flipping the back for more information on strategy. It was mentioned that images communicate the main idea, while subsidiary words help in interpreting the concept. In this stage, the participants explored the paradigms and elaborated on the aims and areas of use regarding the strategies. Furthermore, they thought about how to employ these strategies within the specific packaging problems in the design brief.

Third step is the 'inspiration' phase, where the participants ideated with the assistance of the NDP Card Deck. Guided by the keywords and images, here the participants generated ideas to provide design solutions. In general, it was mentioned that they made use of the principles to relate to nature and paradigms in this part. However it was also indicated that in some cases images were more prominent for associations and *these led them to be influenced in terms of form qualities, whereas information parts were rather useful in developing the functions.* In overall, the participants were stimulated in an unstructured manner in this stage with the design requirements in consideration.

The implementation is the final stage in the process and includes the development of the design solutions. In this phase, the participants conceptualised and visualised their ideas by sketching. Generating several proposals within a problem, some participants provided a number of concepts, whereas there were others who concentrated on a single alternative they found suited to the brief. In general, the packaging concepts were created and communicated within this last step of the design ideation cycle.

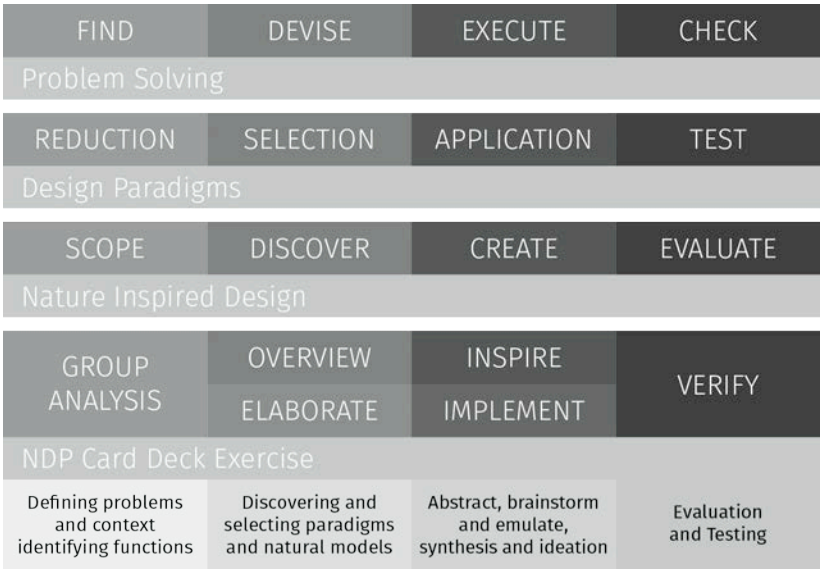



Figure 4.12 – Overlapping Design Processes of Approaches with the NDP Card Deck

The resulting pattern is parallel to overlapping design processes (Figure 4.12). This consequence affirms the expected use of the tool in design ideation stage. However, as the time was limited, the final step of evaluation and testing was mostly eliminated and only one student mentioned that she found time to justify her ideas.

**Most and Least Used Cards**

The paradigms utilised in the second session were examined to understand the preferences of the participants in terms of provided strategies. It was found out that except ‘Spider Web’ and ‘Speckles’ paradigms, each paradigm was used at least once. The most used paradigms were ‘Clamshell’, ‘Telescope’, ‘Honeycomb’ and

'Origami' whereas the least used ones were 'Fur', 'Growth', 'Snake Skin' and 'Cluster'. The findings indicate that the most affiliated strategies were likely to be more familiar ones. The cards were sorted according to their frequency of use in Figure 4.13.

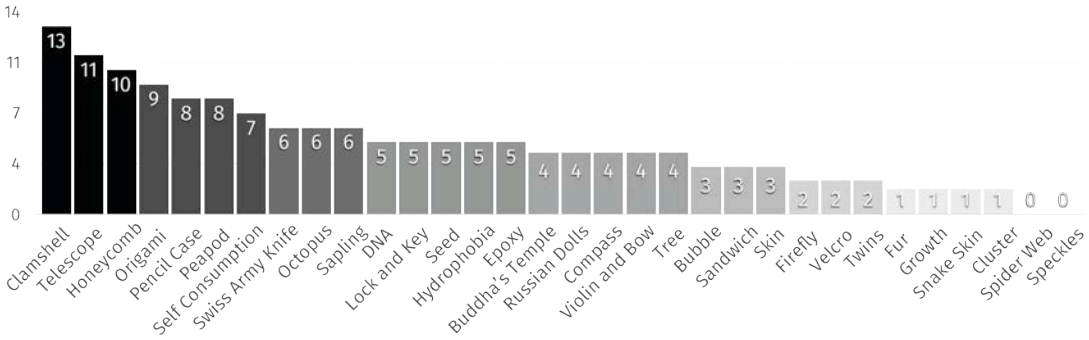



Figure 4.13 – Paradigms According to Their Frequency of Use

**Most Referred Sides and Parts**

As stated in 'Use of Cards' section, the general pattern in using the card deck is referring to both sides of the cards; firstly looking at the images and associating them with the paradigms, and then reading more about the concept. The participants mentioned that some paradigms were obvious whereas there were others that required more information to be grasped. Therefore, through the overview of the cards, cards were explored one by one.

According to some participants the image side was more inspirational (12 students), while some participants found the text side more explanatory and influential (18 students), and there were also participants that referred to both sides equally (10 students). In terms of the frequently used parts, 'aim' and 'where to find' sections were favoured the most.

**Using Single or Multiple Paradigms**

The association of the cards and paradigms within the deck held some possibilities in the utilisation of the tool through the exercise. In addition to choosing and being

inspired from a single card, more than one paradigm could be used in the design process as well. In order to observe the participants' approach on this issue, their behaviour on employing cards, whether individual or combined, was investigated.

The exercise results revealed that 27 out of 40 participants used more than one paradigm in a single design proposal. According to the survey, these participants, either intentionally or not, combined the strategies within a package solution in multiple ways: some participants separated the parts of the package and used a paradigm for each, e.g. honeycomb paradigm for organising the chewing gums and clamshell for opening the lid; some distinguished the properties regarding the form and the function and used different strategies, and some participants combined the paradigms through design, e.g. associating the properties of hydrophobia and elasticity paradigms through the use of silicone material.

These insights on the use of the cards enabled to see the affiliations between the patterns of use. The single and multiple card uses were cross-referenced to the generated idea numbers and the distribution was visualised in Figure 4.14. The participants who were able to generate three or more ideas in both sessions constituted the first group and the other groups followed as the increase, fixed and decrease in idea number.

| | | Paradigm Use in Design Problems | |
|---|---|---|---|
| | | **Multiple Use** | **Single Use** |
| Number of Ideas | **3+ ideas** | 12 Students | 2 Student |
| | **increase** | 8 Students | 3 Students |
| | **fixed** | 4 Students | 5 Students |
| | **decrease** | 2 Students | 4 Students |

Figure 4.14 – Correlation Between Paradigm Use and Number of Ideas

As seen in the graph, the participants who were able to generate a greater number of ideas (12 out of 14) or who were able to increase the ideas they generated in the second session (8 out of 11) used multiple paradigms in a single design problem.

This finding is parallel to the preliminary study results that suggested a relation between the ability to use metaphors in the design process and the creation of multiple variations on a problem. Therefore, it could be argued that there might be a correlation between multiple paradigm use and the increase in number of ideas. However, this study is focused on the idea generation process rather than the generated ideas themselves. On the other hand, this issue may not prove correct as a general rule and needs further clarification with the examination of the ideas in terms of both quantity and quality. Thus, the aspect points to an area that could be investigated in future studies.

### Coherence and Interpretation of the Cards

About the relationship between images, paradigms and the related information, a large part of participants (26 out of 40) expressed that they matched well with a clear connection. However, a group of participants (14 out of 40) stated that the relationship was clear, yet some of the cards were incoherent or hard to associate. This was an anticipated result that occurred in the pilot workshop as well. The intention was to leave space for interpretation, especially with the rather abstract paradigms, such as ‘sapling’, ‘tree’, ‘twins’ and ‘cluster’. However, few participants also pointed out that due to this abstractness, these paradigms were difficult to relate to. In fact, a range of tangible and intangible strategies was provided within the card deck and the evaluation results show that some participants prefer more practical, applicable and transferrable paradigms instead of abstract ones.

The Card Deck was designed in a way to foster the ideation process in an unstructured manner. Therefore the images and the strategies can be associated in an open way and users may get inspired in a different context or perspective. The main study results show that few participants used the cards independent of its contents. The examples can be given as ‘being inspired by the water drop in ‘hydrophobia’ paradigm for the transparency aspect’ or ‘using rotation feature of Swiss army knife instead of all in one strategy’.

#### 4.2.2.3. Nature, Paradigms and Design Relationship

The exercise process supplied an introductory knowledge on nature inspired design, design paradigms and relationship between these concepts. The following sections present the participants' elaborations within these topics.

##### 4.2.2.3.1. Interest in Nature

The exercise influenced the participants positively in terms of nature. Their elaborations mainly point to an increase in the awareness and the knowledge regarding nature inspired design, and an increase in curiosity towards nature for further observation. Prior to main study, the preliminary survey results revealed that participants were informed on nature as an inspiration source for design. The exercise increased this awareness and led them to perceive nature as the origin of time-tested solutions. The participants had previous experience on nature inspired design, however that mainly included form studies without any methodological background on subject. With the workshop, they experienced a hands-on process and gained knowledge on the subject. Introducing an approach on how to observe, interpret and employ the paradigms and strategies existing in our surroundings, the exercise constituted an initial step in looking for design solutions in nature.

Evaluation results also show that, participants appreciated nature on new dimensions besides form, such as function, system and materials. Consequently, having seen various examples on how nature inspires design, the participants were inclined to look at nature, systems and principles more carefully for their future work.

##### 4.2.2.3.2. Paradigms

**Term 'Paradigm' and the Introduced Strategies**

Majority of the participants (29 students) expressed that the term 'Paradigm' was new, yet the concept was familiar. Introduced paradigms and strategies included

both unknown and known elements that participants were not namely conscious of. Participants mentioned that even though they were familiar; it was rather an obscure subject in which they lacked knowledge.

Further comments show that, though participants were aware of some of the strategies presented, they may not be actively using them in their design process. For this reason, the concept was both informative and practical as it illustrates the notion with examples from nature, objects and packaging design ideas. Therefore, a critical approach on paradigms from a design perspective will be developed. Only a few of participants (four students) stated that the concept and its contents were new. There are also a few participants (six students) who were familiar to the term paradigm as well as the most of the strategies; however, the general opinion was that the subject was known yet required further clarification.

*Evocation of Paradigms:* The majority of the participants mentioned that the paradigms were familiar, as the workshop reminded the archetypes and solutions in design language. Strategies included in the presentation and the card deck were common elements found in nature and everyday life, thus participants stated that they frequently encountered these items, yet did not deliberate on. Throughout the exercise, participants acquired introductory knowledge on design paradigms, where they are found and how they can be used in design process, therefore they gained awareness of the subject. Participants described paradigms as ‘easy to understand’ and ‘easy to tell’ key concepts that were almost like a ‘universal language’. They mentioned that after being introduced to the concept, they will eventually/inevitably have such a filter when looking at objects and nature and notice the paradigms employed in products.

*Origins of Metaphors:* Introduction of paradigms for design as a method prompted the participants to question the metaphors they use in design process. Since the design paradigms were presented within a nature related context, the participants were encouraged to think about the origins of forms and functions that were previously irrelevant. A comment by Student 17 puts it this way: *‘I thought the metaphor was the hinge itself, but to see its roots in nature made me think of the source; the nature’*. Another comment refers to a similar point and further states; *‘I*

*am now curious about the origins of metaphors in nature. Though I will use the metaphors while thinking, I will be conscious of nature as a source I can derive paradigms from'*. Thus, it can be stated that the exercise leads participants to think about the way paradigms are reproduced and encourage them to discover new paradigms, instead of memorising the provided selection.

**Paradigm Approach**

The participants were generally in favour of the concept and they referred to the 'design paradigms' approach as a useful, sensible, effective, inspiring and time-saving method. Comments show that they found it effective as a tool for analysing and interpreting nature and objects, and are willing to embrace it for their future studies, even unconsciously. As the design practice has a critical approach by nature, some participants stated they already follow such an attitude without being aware of. This points to the aforementioned use of paradigms in design process, which had an overlapping model to problem solving process.

A few participants described the approach as 'using an existing solution in another problem/area', which is also parallel to the cross-pollination in design process (Kelley & Littman, 2005). A group of participants found the technique surprising, yet there were some participants who found it very inherent to the design process. It was also mentioned that the approach was beneficial as it introduced an additional perspective to be used in the design process. In conclusion, evaluations indicate a familiarity of processes in terms of analysis and synthesis, which enabled the method to be acquired and appropriated comfortably.

#### 4.2.2.3.3. Relationship Between Nature, Paradigms and Design

Participants stated they were aware of the relationship between nature and design on an informational level; nature inspired product stories, famous designers and their products, stylised products and the mathematical relation of golden ratio and its reflections on material world. However, on a metaphorical level, they were not aware of it to this extent. The wide span of examples and the amount of links made

them question the existing principles and perceive the influence and interconnection among nature and manmade world. It also enabled the creation of new associations.

Only two participants mentioned they did not notice such a relationship before, where the majority of the participants agreed that it was hard not to realise it; yet it was a sense rather than a tangible connection that was particularly thought of. The comments by participants on the nature, paradigms and design relationship indicate similar results to the overall evaluation findings. It was primarily mentioned that the exercise drew attention to the links between these concepts; therefore a critical approach and an observational attitude will be acquired.

In general, participants found this relationship intriguing; it was also surprising for them to find out the origins of some forms, mechanisms and principles and how these correspond to design and products. A majority expressed their willingness to inspect and analyse these connections in future. A critical and analytic approach on nature, objects and their design was therefore found effective for design process. As summarised in a comment:

> ‘Paradigms are everywhere, in nature, in our daily lives, our surroundings. We just need to observe, that way we can create simple yet effective design solutions, I realised that.’ (Student 26)

Whether nature or objects, participants became aware of the links that surround our daily lives. The findings show that they are intrigued about these connections and are inclined to observe their environments in future. Also, having seen the connections and accumulation of knowledge now, they are conscious that observation is a continued process, not just a step in ideation process.

#### 4.2.2.4. Personal Assessments

The participants evaluated the exercise in general and referred to several other aspects as they elaborated on the effects of the workshop on their design process. Their assessments include both positive and negative attributions, yet it can be stated

that the overall process was found helpful though it was compelling and challenging. This section presents these thoughts about the process along with the perceived aim and the suggestions for improving the exercise.

#### 4.2.2.4.1. Perceived Aim

According to the survey results, the participants pointed to a number of aspects regarding the aim of the exercise, as they were free to state more than one objective. These perspectives were categorised into main groups regarding nature, paradigms, the relationship of these concepts with design and design process.

*Awareness on Nature (mentioned by 17 participants):* One of the main aims was stated as creating awareness on the nature and the possibilities that it holds for design. The participants mentioned that the exercise was useful as a beginning in learning how to look at nature and inspiring from its strategies in design process. It was also expressed that the process led the participants to observe nature for future inspirations.

*A Critical Perspective on Design Paradigms (mentioned by 13 participants):* The participants stated that the exercise provided a framework on design paradigms in terms of the concept and its utilisation in design process. It was mentioned that the exercise enabled the rediscovery of paradigms present in our daily lives and conveyed a critical perspective on the metaphors and strategies within. The participants found this process helpful in learning about the ways objects and principles inspire idea generation process.

*Association of Nature, Paradigms and Design (mentioned by 8 participants):* The participants referred to the realisation of the relationship between nature, paradigms and design as an aim of the exercise and mentioned that it was achieved through the process. According to comments, the approach and the practice allowed the participants to associate these concepts on a new level and to perceive how principles found in nature and manmade things influenced the design. They

indicated that they would be more aware of the design solutions present in their surroundings.

*Insights on Design Process (mentioned by 6 participants):* Another aim mentioned was gaining of insights on the design process through the exercise. The participants were inexperienced regarding the process, yet they mostly managed to create alternatives in a limited timespan and brainstorm with the help of the card deck. It was also stated that the exercised reached the aim of conveying information on packaging design and its considerations.

#### 4.2.2.4.2. Impact of the Exercise

The implications of the exercise was assessed in within these following major points:

*Seeing a Range of Possibilities (8 participants):* The participants mentioned that it was beneficial to see a lot of options in hand not to choose from, but to reveal multiple paths available simultaneously. Solution sets presented by nature and paradigms affected the perception of participants in a way to make them realise that it is not necessary to invent a brand new system and innovative results can be achieved via cross matching proven methods or solutions within different areas as well. Another advantage of this aspect might be a shift of focus in participants' thinking from 'idea finding' to 'decision making'.

*Acceleration of Design Process (8 participants):* The exercise was specified as an 'activator' that speeds up the process with a specified focus. Additionally, as second year participants expressed they have difficulties in the beginning of the design process, it was stated that the card deck acted as an inspiration source that makes it easier to start the project. It was especially helpful in the fast-paced exercise to enable participants to ideate and express in a quick manner, which has shown what can be done in a short amount of time, according to comments.

*Fundamental Knowledge on the Subject (12 participants):* The participants mentioned that the exercise conveyed essential information on the subjects of nature inspired design, design paradigms, their relation with design and ways of utilising these solutions in design process. As the preliminary study results showed, they lacked knowledge in the introduced approaches. However, according to results, the participants were content on the knowledge provided throughout the exercise.

*Foster Creative Thinking (10 participants):* Assessments refer to exercise as a fostering activity that helps to think and generate ideas. As the workshop presents a defined brief, a problem area and several examples of method found in nature or objects, participants were encouraged to apply the method and achieve results. They were also able to concentrate on the ideation process and alternative design solutions rather than 'the best' solution, thus they were free to speculate on concepts.

*Developing a Critical Approach (14 participants):* It was mentioned that the exercise helped participants to look different with a critical eye on nature and things. Indicating that this was a new design process for them, participants stated they started to look at their environments with a new lens from multiple angles. The method was found to be a perspective widening process that created awareness on aspects and considerations of design as well.

*Association of Concepts (8 participants):* Participants attributed an associative aspect to process, as they expressed it reminded general metaphors and helped to realise the existing links between concepts. The card deck presents paradigms with images and examples from nature and manmade objects. Besides being informative, it thus enables a cross-referenced thinking. It is also stated that this introduction will lead to establishing of further relationships in future.

*Awareness Towards Nature and Paradigms (14 participants):* One of the main achievements is the awareness creation among participants. The participants mentioned that they gained insights on nature, paradigms and their relationship with design, which made them curious to research and observe the nature, manmade objects and their surroundings. As it is discussed in detail in the future projection (see section 4.2.3.4.4), in general, the participants mentioned that they would refer to

nature for in their design process and employ the paradigms approach for analysing products and deriving solutions.

*Improvement by Variations (14 participants):* Another point referred to was the enhanced ideation process. It can be observed that a major part of the participants felt empowered due to the ability to create alternatives with the card deck support. Since the exercise was structured as a brainstorming session, participants expressed the positive impact of the deck on their design process as a stretching, loosening element. As the participants were enabled to generate ideas and variations on concepts in a brief time, they became more comfortable with practice. Additionally, it was mentioned that an improvement in the quality of ideas was observed.

*Insights on Design Process (11 participants):* During workshop process, the presentation, analysis, problem finding and ideation stages helped participants to get a better idea on the design process. Besides learning more about design considerations, packages in particular, they gained a better understanding of sustainability regarding packaging design. Comments indicate that examples included in the presentation and the emphasis of the post-use of packaging made participants realise the potential of the package as a resource.

*Limiting and Compelling Design Sessions (6 participants):* Creating variations on a design problem in a limited timespan stretched and forced the participants' ideation stage. Some participants described this as a positive factor that leads to improvement, however, according to another group; it created a pressure that affected the design process negatively. Two participants referred to the card deck tool as a limiting element in design process. Additionally, developing ideas within a limited time made the exercise compelling according to some participants.

#### 4.2.2.4.3. Difficulties and Suggestions

The evaluations of the participants pointed to some aspects regarding the difficulties experienced during the exercise and included suggestions for further improvements of the method and the card deck.

### Time Allocation

One third of participants (13 out of 40) found the amount of time enough for idea generation. Some of them stated they were comfortable with working in short successive sessions, yet some mentioned that the limit was appropriate for ideation however more time would be required for detailing. Other two third (26 out of 40) found the allocated time not enough, leading to a compelling and stressful process.

This is mainly due to that they are not familiar with such a fast-paced design process and are having difficulties in finding ideas and sketching them quickly. The suggestions included a decrease in number of design problems/brief and/or an increase in the time allocation.

### Duration

Besides time limit per concept, total duration of workshop with successive sessions was mentioned as a tiresome factor. It was suggested that the exercise could be extended over a longer period or days. The participants mentioned that the stages of the exercise would be more refined within a longer duration.

### Difficulties in Inspiring from the Cards

According to the comments, three participants had problems in concept generation with the utilisation of the cards either because they found it difficult to transfer design solutions or associate strategies. This might also due to the number of design problems, as they found it hard to generate multiple ideas in sequel.

### Design Communication Abilities

Although mentioned by few participants (three participants), the ability to quickly sketch and communicate the ideas addressed a problem for the second year design participants. As they were not experienced in ideating through drawing within short durations, both the quality and the quantity of the outcomes were limited to their skills in design communication.

**Language**

As mentioned before, the language of the cards was another factor that affected the design process negatively. 16 out of 40 participants stated they had difficulties related to the non-native language of cards. Though they managed to comprehend the meanings through context and help of the participants and facilitators, they mentioned it was preferable to have the cards in Turkish for ease of use.

#### 4.2.2.4.4. Future Projection

The participants evaluated the approach positively in general. For their future use of the both perspectives – nature inspiration and design paradigms – their assessments are as following.

Regarding the paradigms approach, the participants mentioned that it is useful in analysing the products (five students) and for the design process (14 students). 37 participants out of 40 mentioned that they would use the paradigmatic thinking in their future works. The remaining participants were in favour of the approach as well, though they did not specified that they would adopt the approach.

As for nature, all of them (40 students) stated that they would observe and inspire from nature in their future design processes. Seven participants indicated that they were already referring to nature, yet with this exercise they learned how to use nature inspiration in design along with various methods and tools.

The participants were aware that the exercise was an initial step in a learning process, which would only be possible with personal reflection and experiences through a period of time. Consequently, the nature design paradigms approach was perceived not only as a method to be utilised in the design ideation phase, but also as a way to relate to the nature and products.

### 4.3. Student Cases

This section aims to investigate the utilisation of the nature design paradigms approach and the NDP Card Deck in design process by examining a selection of outcomes of the exercise along with the evaluations of the participants.

These cases represent examples from six groups from increased or unchanged number of ideas as illustrated in Table 4.2. The student cases were selected with regard to their use of the approach and the card deck, the variety in the ideation process, the considerations and the dimensions within the proposed design solutions.

Table 4.2 – The Placement of the Cases According to The Grouping of the Students

| | | Students' Assessments on Their Performances | | |
|---|---|---|---|---|
| | Groups | 1 POSITIVE | 2 NEUTRAL | 3 NEGATIVE |
| Change in the Number of Ideas | a- INCREASE | Student 1 | Student 15 | Student 20 |
| | b- FIXED | Student 33 | Student 7 | - |
| | c- DECREASE | - | - | Student 30 |

#### 4.3.1. The Case for Student 1

Student 1 was in Group 1a, as she regarded her exercise process positive and had an increase in number of ideas. Her use of the nature design paradigms approach and the card deck are presented along with her insights on the process.

**Exercise Outcomes for Student 1**

Student 1 submitted two ideas for dragee and toothpaste packages in Session 1 (Figure 4.15) and three ideas in Session 2 (Figure 4.16). For the first session ideas, it seems that she was influenced by the examples in presentation. She considered the dispensing of items and aimed for an ease of use. In both problems, the solutions were focused on the opening parts of the packages. The dragee package uses an

elastic push button for single disposal of gums. The toothpaste package, on the other hand, utilises a soft part instead of a plastic lid and is squeeze opened with pressure (Figure 4.15).

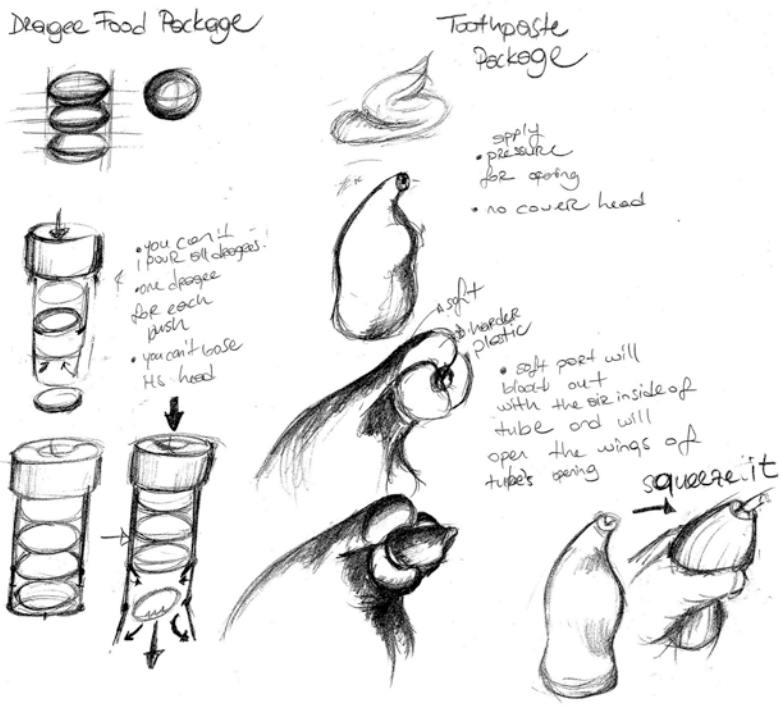



Figure 4.15 – Exercise Outcome for the First Session by Student 1

In the second session, she made use of several strategies by combining two paradigms for each design problem. For the dragee package, she proposed an elastic cover that holds the items within. Inspired by the peapod and the sapling principles, the solution wraps the gums inside, disposes items singularly and gets smaller by the surface pressure with each disposed gum.

For the matchstick package, she made use of pencil case and self consumption strategies and developed a concept where matchsticks are combined into a whole to eliminate the outer package. Idea suggests the detaching of matchsticks from its base one by one and therefore prevents the matches to be scattered.

For the third concept, she employed self consumption and sapling principles and created a balloon-like toothpaste package that shrinks upon use. The pack has a

rotary lid that is press opened and the paste comes out while holding and squeezing (Figure 4.16).

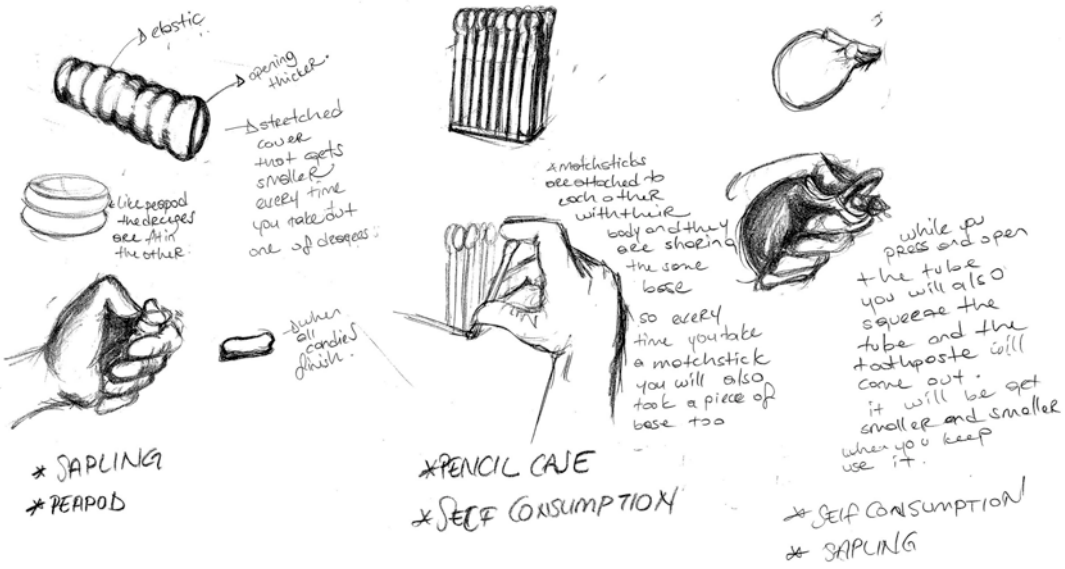



Figure 4.16 – Exercise Outcome for the Second Session by Student 1

Through the exercise, Student 1 made use of several design strategies from nature and generated ideas with considering ease of use and disposal of the package. Her design solutions include a variety of dimensions that investigate form, function and materials of the packages.

**Results for Student 1**

The survey results that are summarised according to the content analysis categories are presented in Table 4.3.

As seen in Table, Student 1 was generally content with the nature design paradigms approach and the card deck exercise. She indicated that the exercise led to the association of concept and the acceleration of design process by providing possibilities in hand.

Table 4.3 – The Categorised Results for Student 1

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | Found the subject interesting and perspective widening. It supported design process and provided a critical perspective. |
| | Design Brief | Lead to think multiple problems at once. Found it easier to think different subjects rather than being stuck in one. |
| | Conduct of Exercise | Beneficial to learn analyses of others. |
| Appropriation of Card Deck | Design of the Cards | Simple design, visuals are interesting, content is clear. Paradigms and images were related. Referred to text side most. |
| | Use of the Cards | Browsed one by one, selected the ones to be used. Designs appeared during this stage. Combined multiple strategies in ideas. |
| Nature, Paradigms and Design | Nature | Gained awareness on looking for design solutions in nature and utilising them in design process. |
| | Paradigms | New phrase, yet familiar concept, principles were known. Influenced to look carefully at objects and things to understand and use these strategies. |
| | Relation with Design | Was aware, yet it was interesting to see, led to make further new connections between things. |
| Personal Assessment | Implications of Approach | Seeing a Range of Possibilities, Acceleration of Design Process, Association of Concepts. |
| | Perceived Aim | To make use of nature in design process for better and sustainable solutions. At least creating an awareness. |
| | Difficulties & Suggestions | Other than problems with time limitation, it was fine. |
| | Future Use | Will inspect nature and use the NDP approach in future design processes. |

She mentioned that the aim was to make use of nature in design process for more efficient and sustainable design solutions. She stated that she gained awareness on nature and paradigms and will inspect these in future design processes as well as with the nature design paradigms approach.

### 4.3.2. The Case for Student 33

Student 33 was in Group 1b, as she was content with her exercise process with a submission of equal number for each session. The outcomes she submitted are

analysed and results on the exercise and the card deck tool with her evaluations are presented below.

**Exercise Outcomes for Student 33**

Student 33 submitted four concepts for each session with one shared idea, therefore presented a design solution for each packaging problem (Figure 4.17, Figure 4.18 and Figure 4.19).

In the first session, she presented a variety of lids in general with opening and dispensing considerations. A push-dispensed chewing gum pack, a double-sided transparent matchstick pack and a hinge-opened toothpaste pack constitutes the outcomes for session 1 (Figure 4.17).

For the second session, she combined a variety of paradigms for the card deck inspired solutions. As seen in Figure 4.18, she was influenced by octopus and created a chewing gum pack with suction-cup shaped containers. The multiple tastes are offered in one pack within stacked columns.

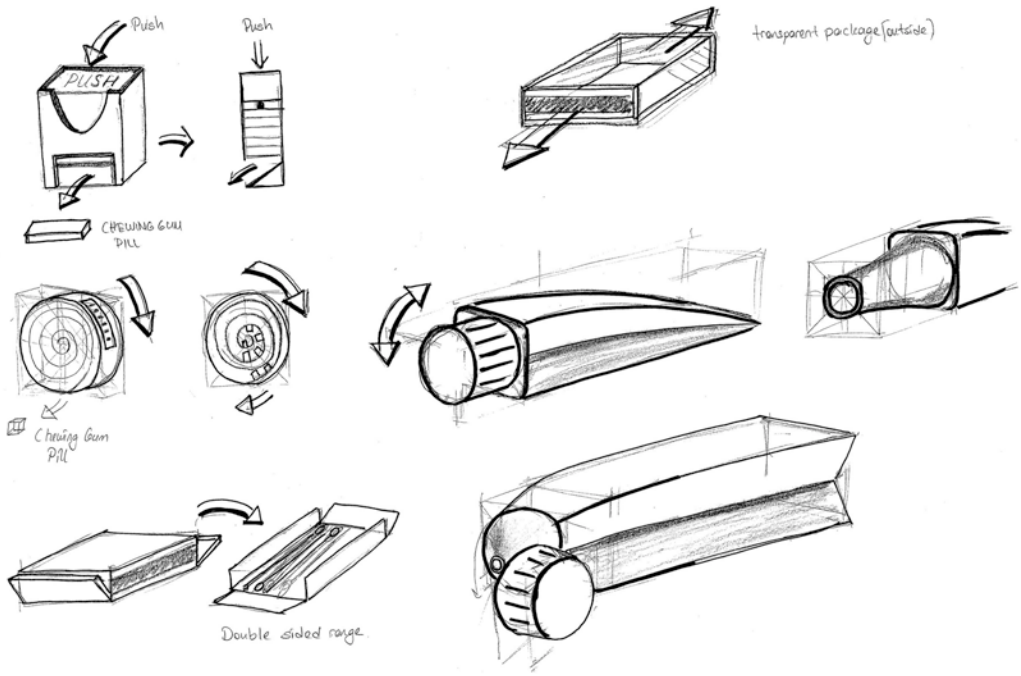



Figure 4.17 – Exercise Outcome for the First Session by Student 33

The second concept was inspired by twins and all-in-one paradigms mainly and consisted of the combination of bleach and toothpaste within a double tube pack. In the third concept, she examined the disposal of a matchstick and continued to ideate on a multiple openings.

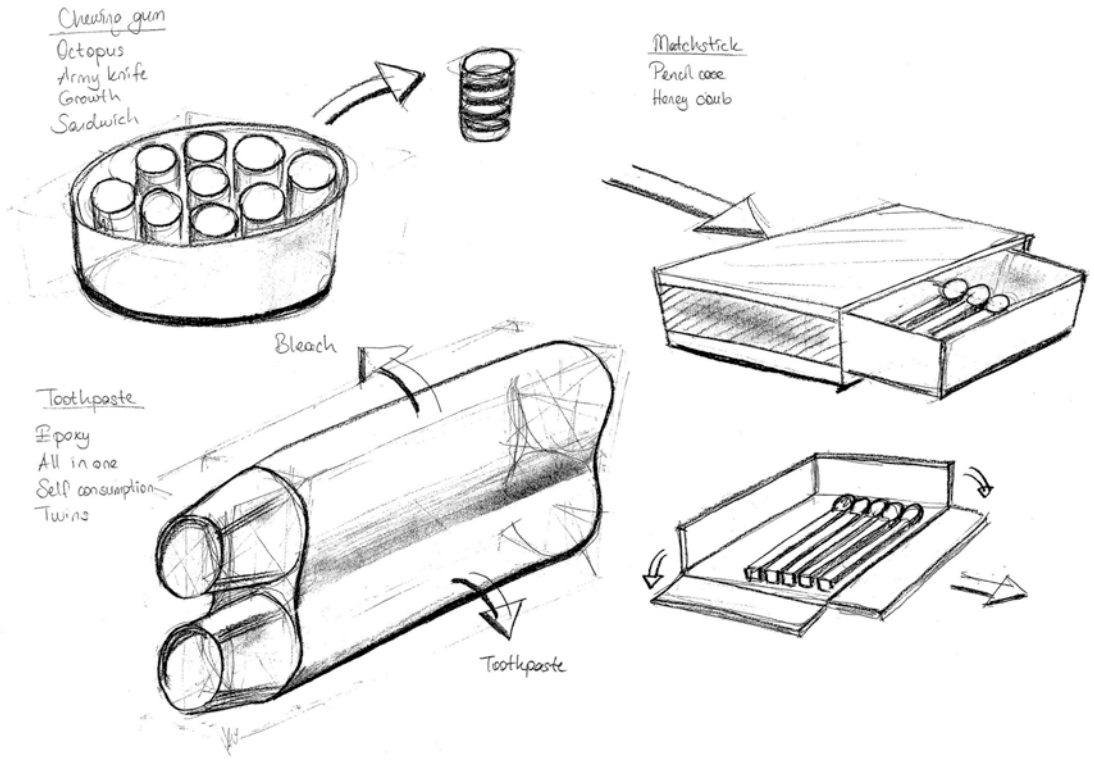



Figure 4.18 – Exercise Outcome 1 for Second Session by Student 33

The last design solution of Student 33 shifts the concept of the toothpaste from a paste form to a pill form (Figure 4.19). Inspired by the bubble paradigm, she proposed a single-disposal toothpaste package, in which the one-time use capsules melt with water. This idea is interesting, as it seems to be derived from the considerations of other briefs. It might also be resulted from the association of a medicine pack through the bubble paradigm. All in all, it points to a flexibility of thinking towards the end of ideation process.

Throughout the process, Student 33 utilised multiple paradigms from the deck and developed concepts that investigate the containing and disposal of items. The ideas she presented include multiple dimensions as form, function and materials of packaging and further explore the transfer and shift of metaphors.

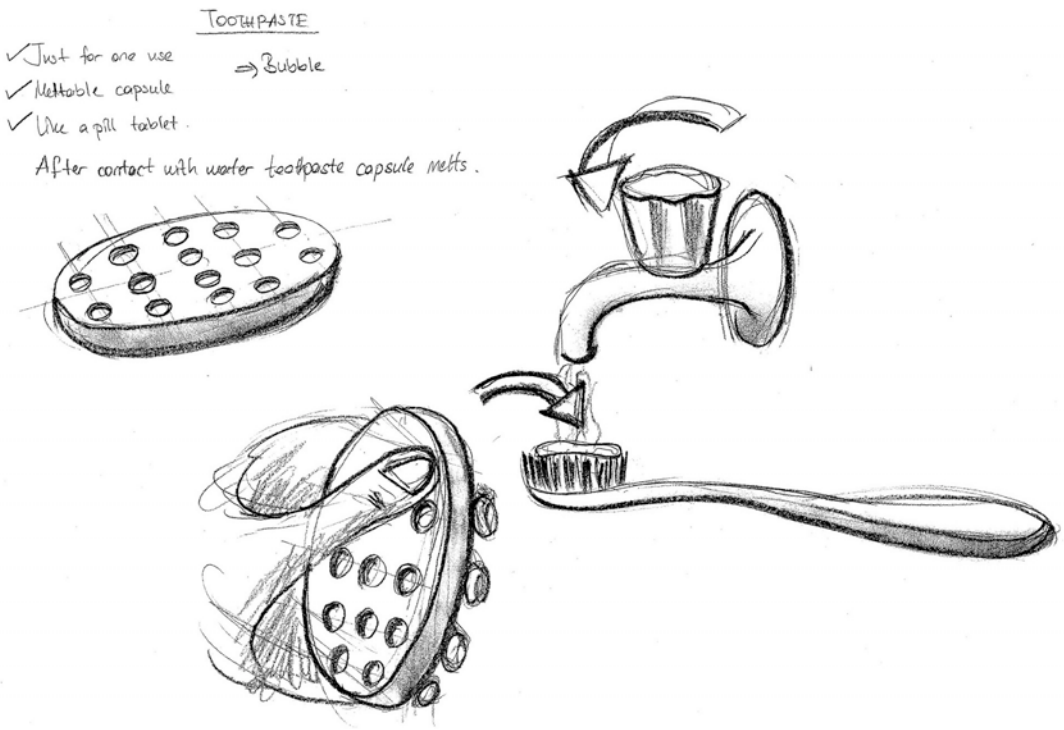



Figure 4.19 – Exercise Outcome 2 for the Second Session by Student 33

**Results for Student 33**

The survey results that are summarised according to the content analysis categories are presented in Table 4.4.

As presented in Table, Student 33 was generally satisfied with introduced approach and ideation tool. She expressed that the exercise provided an enhanced ideation process by presenting strategies in a physical form. She stated that the aim was to acquire knowledge on the subject via learning with doing and she did learned about the concept as well as the design process.

She mentioned that the duration of the exercise posed some difficulties, yet she was contented. She indicated that she would refer to nature, paradigms and the relationship in future studies.

Table 4.4 – The Categorised Results for Student 33

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | Informative, presented essential information on the subject with captivating visuals. |
| | Design Brief | Each had different aspects and criteria, was more beneficial to think in varied subjects. |
| | Conduct of Exercise | Following a collective thinking, individual work was necessary to reflect personal approaches. |
| Appropriation of Card Deck | Design of the Cards | Images were important to stimulate and keywords were clear. Content and design were coherent. Used image side more. |
| | Use of the Cards | I followed the linear introduction through name, visual, examples and explanations. Used multiple cards in design process. |
| Nature, Paradigms and Design | Nature | Was impressed with the examples from nature and realised that nature is a great source for design and should be referred. |
| | Paradigms | Mostly new, learned the names of familiar ones as well. Found very useful, will be thinking of them. |
| | Relation with Design | Was aware but not to this extent. Encouraged me to investigate further. |
| Personal Assessment | Implications of Approach | Learned a lot on design process&methods, having strategies in a physical form made it easier to think, saw what can be done in a limited time. |
| | Perceived Aim | Being informed and learning by entertaining, exercise reached the point. |
| | Difficulties & Suggestions | Content with the exercise, yet the long duration made it difficult to think in some occasions. |
| | Future Use | Thinks of using nature and paradigms approach in future studies. |

### 4.3.3. The Case for Student 15

Student 15 was in Group 2a, as she/he was optimistic about her exercise process and the outcomes with an increase in number of ideas. The design solutions the student submitted are analysed. The findings on her use of nature paradigms approach and the card deck tool are presented below with her insights on the process.

**Exercise Outcomes for Student 15**

Student 15 submitted one concept for matchstick package in session 1 (Figure 4.20) and three concepts including one idea for each problem in session 2 (Figure 4.21).

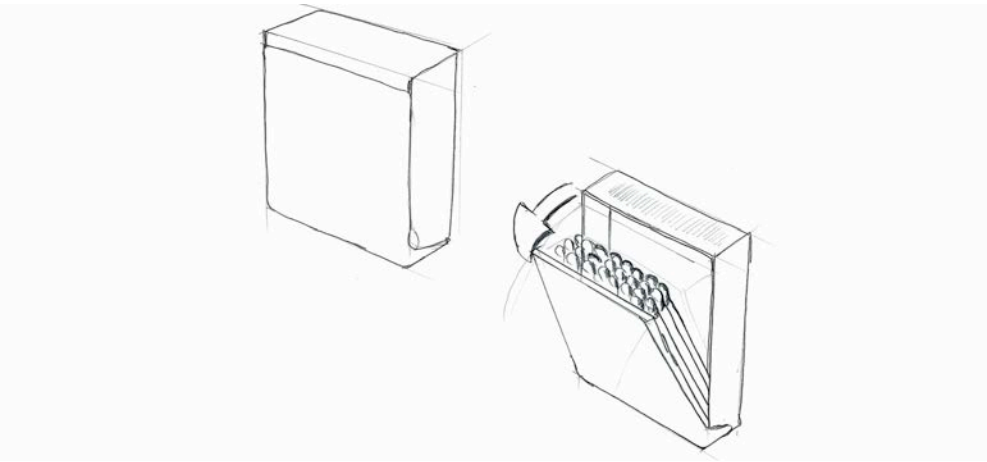


Figure 4.20 – Exercise Outcome for the First Session by Student 15

In Session 1, the student presented a matchstick pack that opens with a rotary-hinged lid. By considering the way that package works, she created an unconventional, yet existing alternative to design problem. However, the influence of the presentation can be seen through the use of 'clamshell' example (Figure 4.20).

For the second session, the student developed one solution for each problem with the support of the deck, three ideas in total (Figure 4.21). She utilised a single design paradigm for each design idea. In the first concept, the student proposed an origami inspired matchstick package design that folds up and becomes a candleholder in its post-use. This is one of the few ideas in the exercise that hold sustainability concerns.

The second concept presents a toothpaste package inspired by telescope paradigm. Functioning through the segments that slide over each other, the idea recalls a liquid-soap pack in terms of its form. The solution ideates the toothpaste pack as a stationary container over the counter.

For her last concept, the student generated a gum/candy package that wraps each item separately and disposes singularly. Inspired by pencil case strategy, the packaging idea becomes smaller through use.

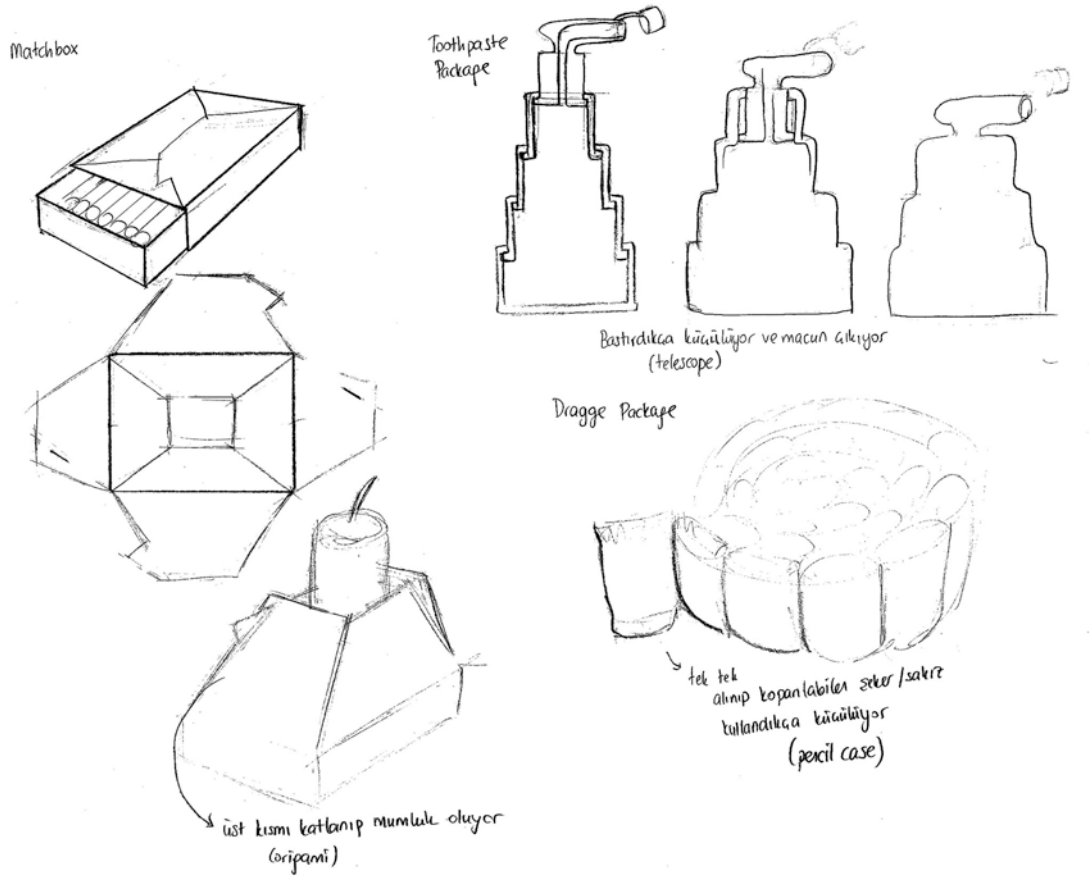



Figure 4.21 – Exercise Outcome for the Second Session by Student 15

Through the exercise, Student 15 employed a single strategy in her/his design proposals and created concepts that explored both the use and post-use of the packages through different forms and mechanisms.

**Results for Student 15**

The survey results that are summarised according to the content analysis categories are presented in Table 4.5.

As concluded in Table, Student 15 was optimistic about the exercise and assessed the approach as an initial point in ideation process. The student indicated that the workshop introduced an effective tool in inspiring from nature and helped with the design process by enabling a range of strategies.

Table 4.5 – The Categorised Results for Student 15

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | Informative, examples were interesting. |
| | Design Brief | Beneficial to generate ideas on a differed range. |
| | Conduct of Exercise | Was useful to conduct analysis in a collective way and to learn about comments and thoughts. |
| Appropriation of Card Deck | Design of the Cards | Found it stimulating. Yet, some images were irrelevant. Mostly used text side. |
| | Use of the Cards | Started out with the 'aim' part, referred to examples when needed. Used single paradigm for each problem. |
| Nature, Paradigms and Design | Nature | I think nature has contributed a lot to design. Improved myself on observing nature. |
| | Paradigms | Were mostly familiar, helped to interpret the elements in nature and objects. |
| | Relation with Design | Was aware but not to this extent. I am intrigued to discover new links. |
| Personal Assessment | Implications of Approach | Effective tool in inspiring from nature. To see a range of options from nature made me think easier and faster, helped with the design process. |
| | Perceived Aim | Conveying information on nature and paradigms and to see how they reflect to design as a result. I think I achieved this aim. |
| | Difficulties & Suggestions | Time was not enough as I couldn't draw fast. |
| | Future Use | Thinks that having a variety of approaches support the design process and considers using the approach in future projects. |

She stated that the exercise aimed to convey information on nature and paradigms and to assess their reflection on design process. The student mentioned that she intends to use the approach as she thinks that having various approaches support the design process.

### 4.3.4. The Case for Student 7

Student 7 was in Group 2b, as she was optimistic about her exercise process and the outcomes with a steady number of ideas. The design solutions and the ways she made use of the approach and the card deck are presented along with her insights on the design process.

**Exercise Outcomes for Student 7**

Student 7 submitted more than three concepts with variations in both sessions (Figure 4.22, Figure 4.23 and Figure 4.24). It should be mentioned that Student 7 had a particular approach on the exercise as she ideated by freely sketching variations on the themes. Prior to idea generation, she concentrated on the context and posed aspects for each design problem.

In the first session, she focused on the design considerations for packages, and specified some criteria regarding their design and use (Figure 4.22).

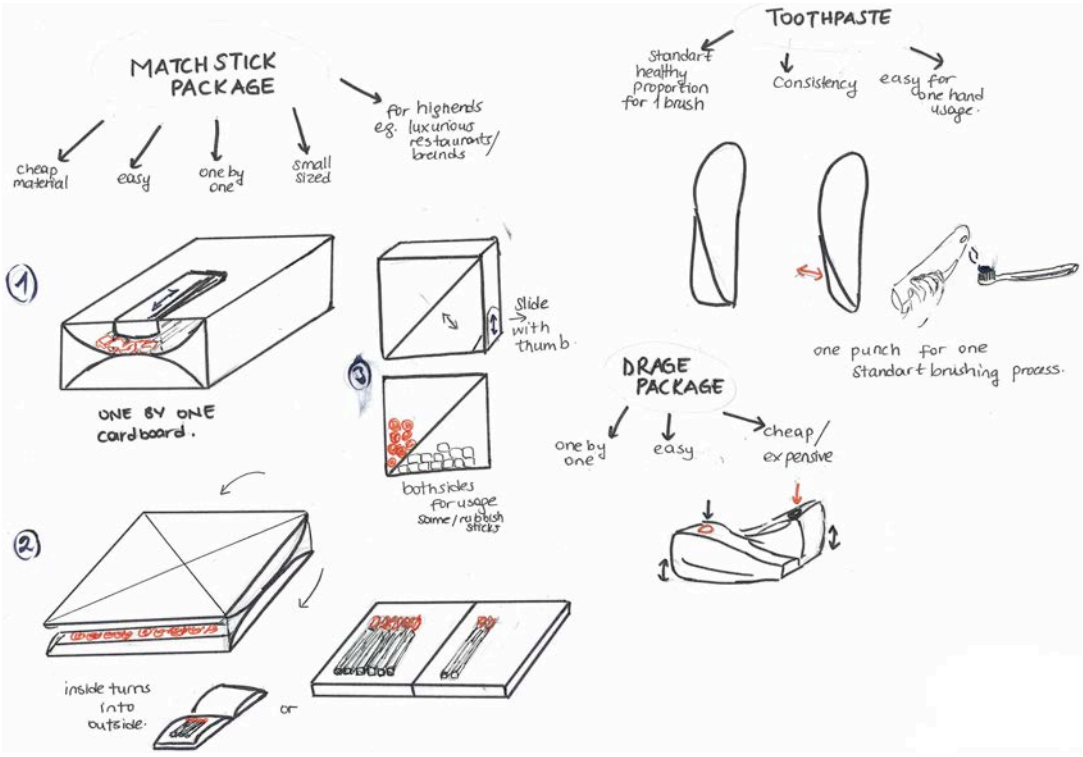



Figure 4.22 – Exercise Outcome for the First Session by Student 7

For the matchstick pack, she defined the requirements as being cheap, easy to use, one by one disposal and small sized package that can be produced for high-end restaurants as well. Upon these, she presented various proposals on the opening, containing and disposal of matches.

For the second concept, she followed a similar way and proposed an easy, single hand use toothpaste pack that disposes same portion each time with one press. As for the third problem, she generated a dragee pack with two opposing containers that hold different items.

For the second session, she developed ideas focusing on single paradigms (Figure 4.23). Her first concept is a toothpaste pack that originated from the origami paradigm. The idea presents a folding pattern as a solution for easy squeezing and features a vacuum head for sticking the tube.

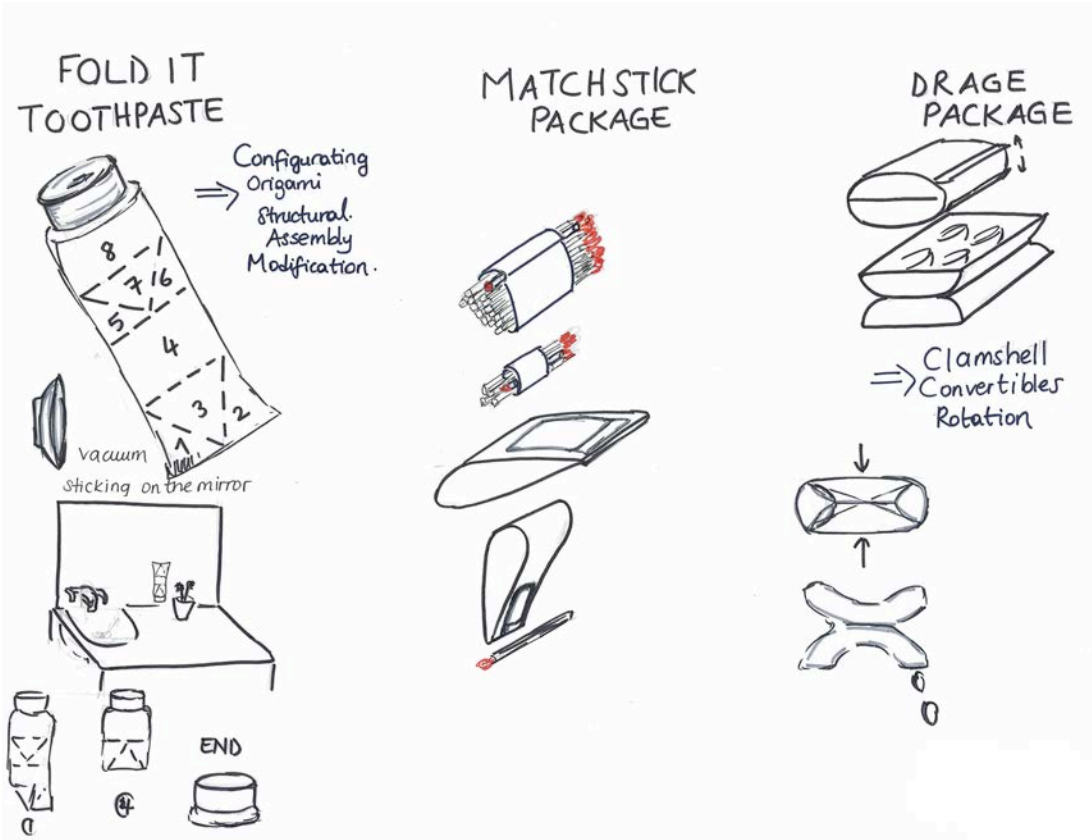



Figure 4.23 – Exercise Outcome 1 for the Second Session by Student 7

Her ideation for the matchstick package in second session features a wrapping band as a pack that holds the matches together, yet no strategies are specified.

As a third concept, she proposed a dragee package inspired from the clamshell paradigm, where the pack is opened and items are disposed through a hinge mechanism.

Lastly, she presented a single use toothpaste package that was developed using origami strategy (Figure 4.24). The concept can be utilised as a promotional, disposable package, whereas a variety of forms and colours are available for adults and kids.

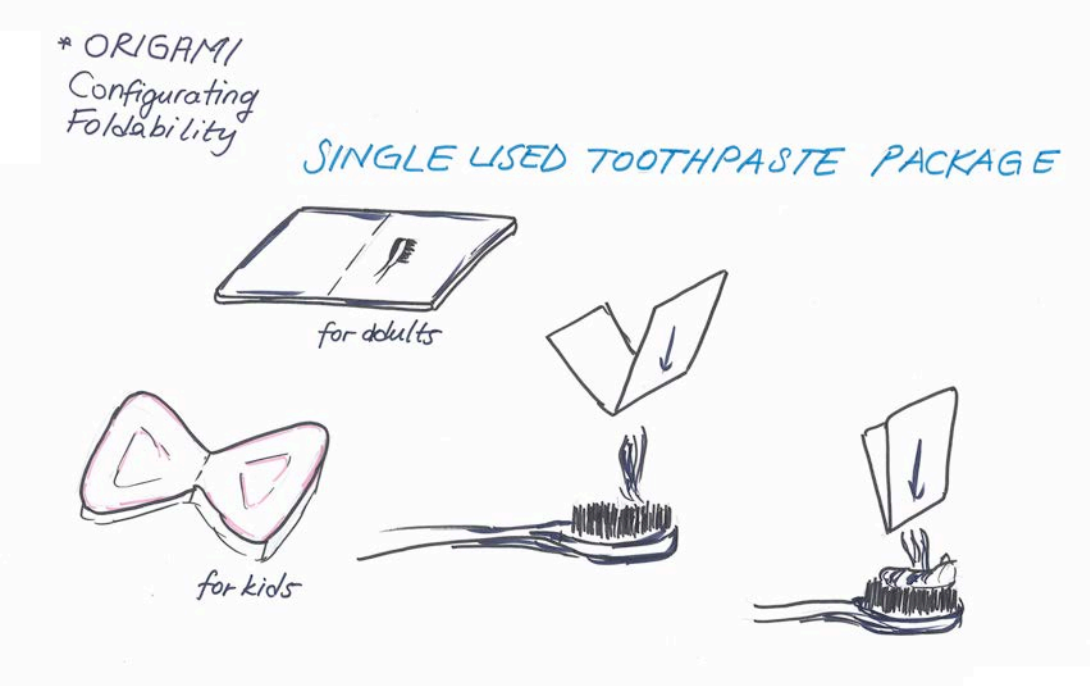



Figure 4.24 – Exercise Outcome 2 for the Second Session by Student 7

Throughout the design process, Student 7 concentrated on a single paradigm for design proposals and ideated concepts that inquired the use of the packages along with their context via a variety of forms and strategies.

**Results for Student 7**

The survey results that are summarised according to the content analysis categories are presented in Table 4.6.

Table 4.6 – The Categorised Results for Student 7

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | Found it effective and informative, learned some foundational knowledge on the subject, which we lacked. |
| | Design Brief | Compelling yet made us think on different aspects while considering other design problems in the background of our brains. |
| | Conduct of Exercise | The conduct was positive, yet would be more effective to have one of the concepts as group work. |
| Appropriation of Card Deck | Design of the Cards | Images and paradigms were relevant. Mostly associated with a couple exceptions. Used the specifications part. |
| | Use of the Cards | Used keywords, specifications and images to lead my designs. Would have associated multiple paradigms if had more time. |
| Nature, Paradigms and Design | Nature | I was already inclined to nature, exercise made me more excited. |
| | Paradigms | Heard the term, yet was unclear. Exercise was explanatory on paradigms, some strategies were new. |
| | Relation with Design | I was aware through studies of junior students, some designs and products. Captured my attention. |
| Personal Assessment | Implications of Approach | Effective, learned about design strategies and their uses, nature influence in design, paradigms and packaging. |
| | Perceived Aim | Creating awareness w/o need of any background by presenting paradigms and their utilisation in packaging, enabling different perspectives. |
| | Difficulties & Suggestions | Time limit was not enough, it should be either longer or number of design problems should be reduced. |
| | Future Use | Considers using the approach in future projects. |

As presented in Table, Student 7 was optimistic about the exercise and evaluated the approach as an initial point in ideation process. She stated that the exercise was informative on design strategies and their uses, nature influence in design and packaging subjects. She mentioned that the aim was to create awareness without the necessity of a background. As she expressed that the allocated time was not enough,

she suggested that the time limit can be increased or the number of design problems can be decreased. She noted that she considers using the approach in future projects.

### 4.3.5. The Case for Student 20

Student 20 was in Group 3a, as he was not satisfied with his exercise process and the outcomes though there is an increase in the number of ideas he generated. His design solutions and his use of the approach and the tool are presented with his insights on the exercise process.

**Exercise Outcomes for Student 20**

Student 20 presented ideational sketches for the first session (Figure 4.25 and Figure 4.26), whereas he submitted four concepts for the second phase (Figure 4.27, 4.28, 4.29 and 4.30). It could be noted that Student 20 had an unstructured way of ideating with design considerations and generated solutions were mixed within sketching process.

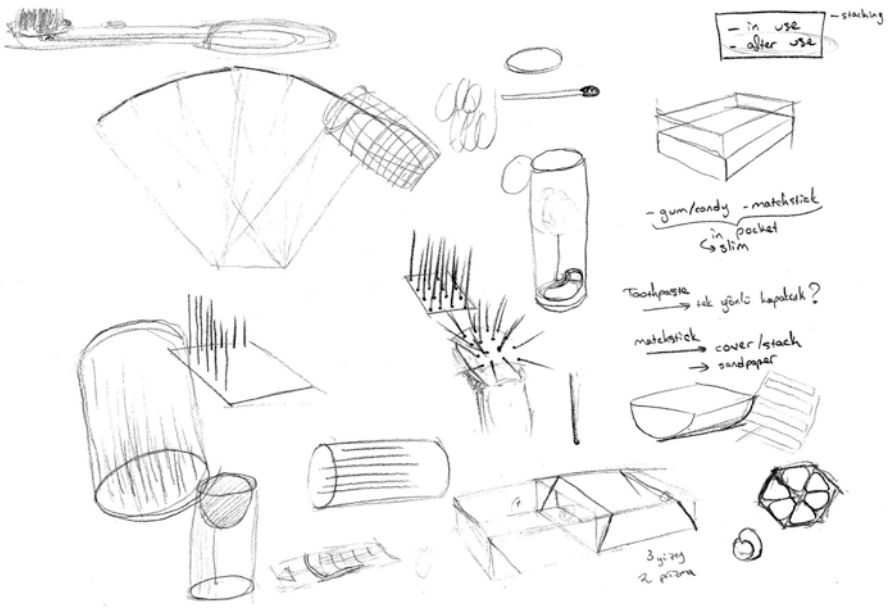



Figure 4.25 – Exercise Outcome 1 for the First Session by Student 20

For the first session, he ideated and sketched freely on concepts, speculated on the aspects and generated various forms on each design problem, yet only submitted a matchstick package idea with a curved form (Figure 4.26).

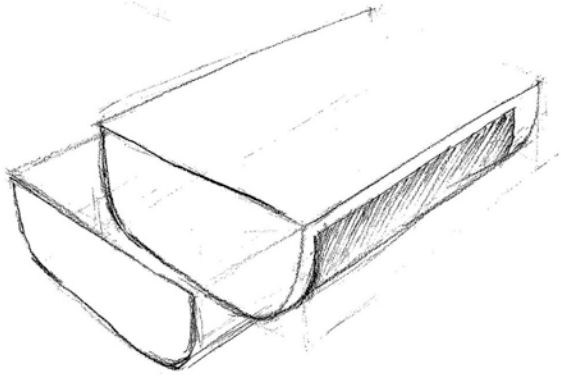


Figure 4.26 – Exercise Outcome 2 for the First Session by Student 20

In the second session, he utilised the cards as both singular or multiple strategies and proposed several concepts on the design problems. For the matchstick package, he developed two ideas; his first proposal actually includes an all in one strategy (Swiss army knife), yet he was inspired by the 'clamshell' and 'violin and bow' paradigms. The concept combines cigarettes with matches in a custom cigarette case (Figure 4.27).

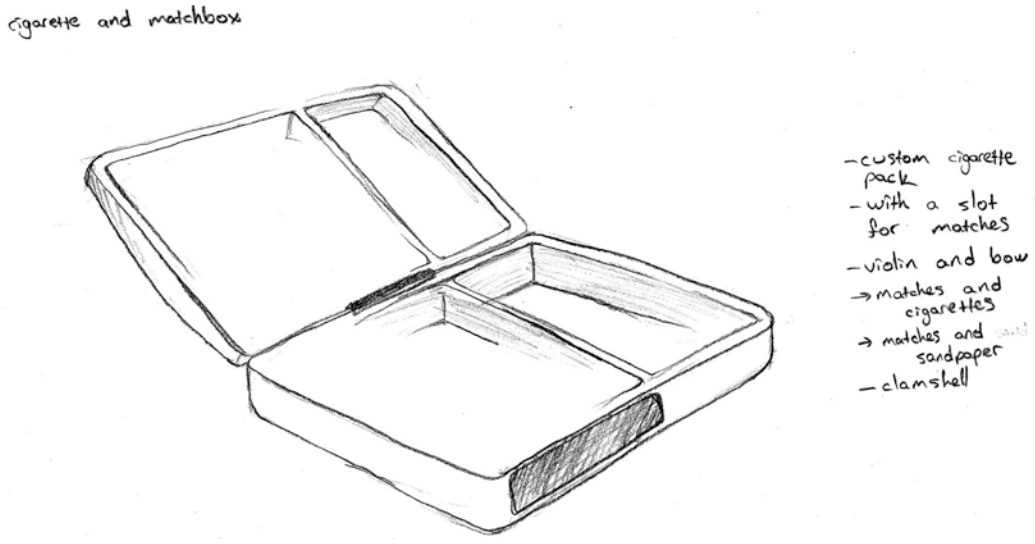



Figure 4.27 – Exercise Outcome 1 for the Second Session by Student 20

As a second concept, he proposed a glowing matchstick package that is originated in the 'firefly' paradigm (Figure 4.28). Though in a conventional form, his idea presented a bigger matchstick pack for home use that can be easily found in the dark.

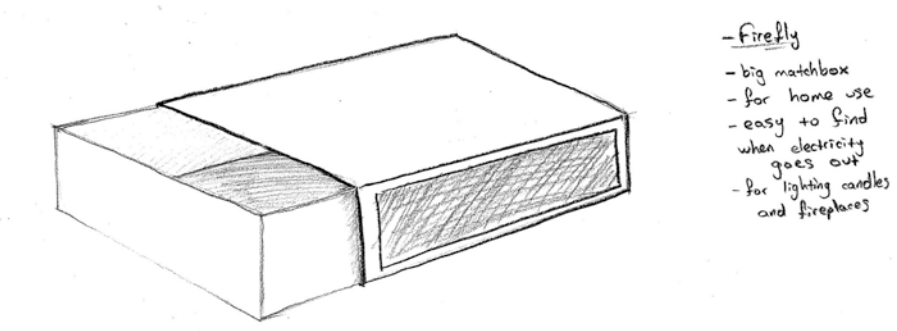



Figure 4.28 – Exercise Outcome 2 for the Second Session by Student 20

For the third concept, he developed a toothpaste pack with sustainability considerations. Inspired by the octopus paradigm, the idea presents a vacuum lid for attaching the pack to several surfaces in bathroom (Figure 4.29). In turn, the attachable lid becomes an accessory in its post use and can be used as a towel holder etc.

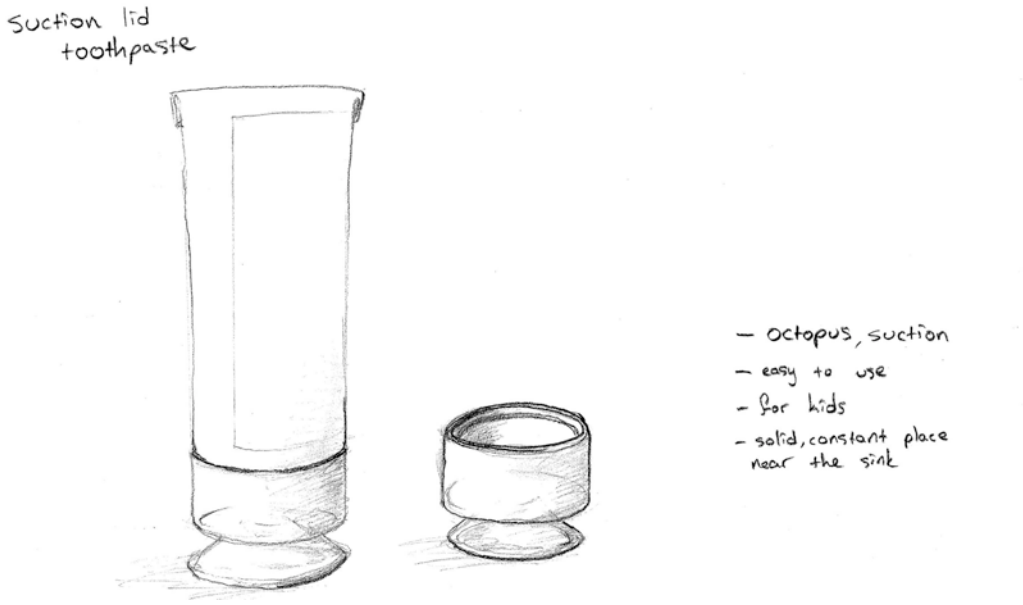



Figure 4.29 – Exercise Outcome 3 for the Second Session by Student 20

His last concept was developed for the candy package problem. The idea was inspired by the honeycomb and skin paradigms as the pack was shaped in a hexagon form and wrapped with an outer foil (Figure 4.30).

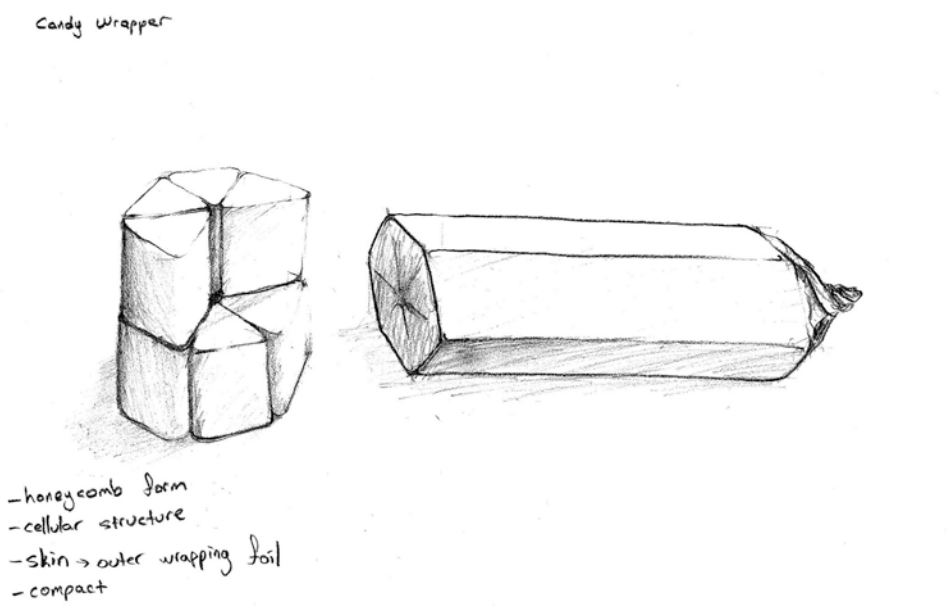



Figure 4.30 – Exercise Outcome 4 for the Second Session by Student 20

Through the exercise, Student 20 employed various strategies for his design solutions and generated ideas that focus on the form, function, materials and context of the packages.

**Results for Student 20**

The survey results that are summarised according to the content analysis categories are presented in Table 4.7.

As stated in Table, Student 20 was dissatisfied through his outcomes from the exercise yet he could develop ideas with an increased number. He stated that the exercise constituted an introduction to both nature paradigms and a new design process/thinking. He mentioned that the aim was to present the paradigm approach along with utilisation in nature, objects and design process. He indicated that the

time limitation created a pressure and led to a stressful process. Lastly, he expressed that he will observe the nature and use the design paradigms analysis inevitably in the future, yet he would not design solely with paradigm utilisation purpose.

Table 4.7 – The Categorised Results for Student 20

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | A required step before the practical session. |
| | Design Brief | Lead to think of a variety of solutions as each package problem presented different criteria and aspects. |
| | Conduct of Exercise | Was useful and enjoyable to conduct analysis as group, would be more productive to have the ideation as group too. |
| Appropriation of Card Deck | Design of the Cards | Images were more explanatory than keywords. Design&content were coherent. Number of examples can be increased. |
| | Use of the Cards | Examined cards, thought how to use. Separated the inspirational ones and utilised in ideation. Used multiple paradigms w/o being conscious. |
| Nature, Paradigms and Design | Nature | I used to examine nature to find solutions to design problems. I realised the vice-versa is useful and enjoable as well. |
| | Paradigms | I didn't know their names, yet was familiar with concept and nearly all paradigms. They constitute a universal language in describing things. |
| | Relation with Design | Was aware, it is hard not to notice it. They exist in our daily lives and consciousness. |
| Personal Assessment | Implications of Approach | Was introduced to paradigms and a new design process and thinking. Yet I don't think I would design solely with paradigm utilisation purpose. |
| | Perceived Aim | To answer what is a paradigm, where and how they are used, how to utilise them in design process. It achieved this aim. |
| | Difficulties & Suggestions | A useful tool to arrive design from nature. But time limitation made pressure. |
| | Future Use | Will observe nature and use the design paradigms analysis inevitably. |

### 4.3.6. The Case for Student 30

Student 30 was in Group 3b, as she was dissatisfied about her exercise process and the outcomes with a steady number of ideas. Her design solutions and the ways she

made use of the nature design paradigms approach and the card deck are presented along with her insights on the design process.

**Exercise Outcomes for Student 30**

Student 30 submitted more than three concepts with variations in both sessions (Figure 4.31, Figure 4.32 and Figure 4.33). It should be noted that Student 30 had a free ideation process in the first session where she sketched a number of ideas. However, in the second session she followed a more structured process with the card deck tool and ended up with a decrease in the number of ideas.

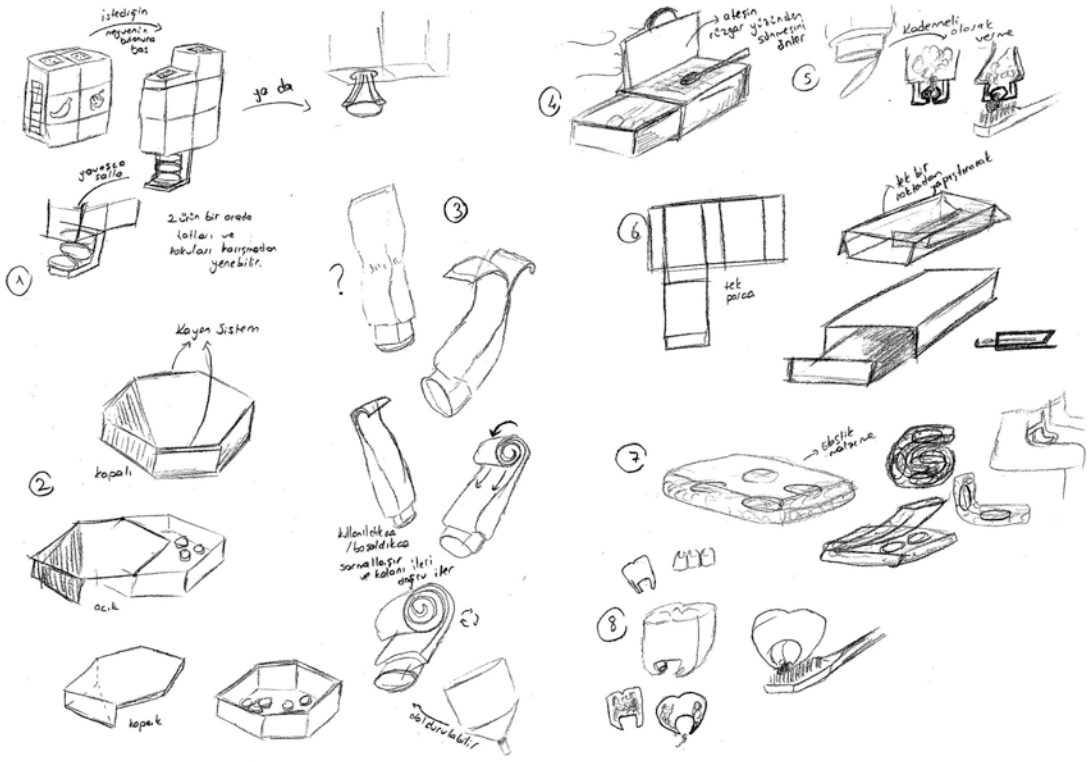



Figure 4.31 – Exercise Outcome for the First Session by Student 30

In the first session, she focused on the use of packages and proposed various forms and mechanisms as design solutions, just like they did with the design paradigms exercise in the preliminary study. For the chewing gum pack, she generated an idea that release different flavours from separate chambers. Additionally, she created a sliding pack and an elastic container for this theme (Figure 4.31). For the toothpaste

brief, she proposed a tube geometry that can be rolled up and refilled. In addition, she suggested the portioning of the paste through the lid and generated a tooth-formed concept. As for the third concept, she created a matchstick pack with a windshield and suggested a one-piece geometry that can be folded into a pack.

For the second session, she utilised a single design paradigm for each theme. Her matchstick pack was inspired from the buddha's temple paradigm and aimed to eliminate the outer package that holds the matchstick packages together by slide-stacked packs (Figure 4.32).

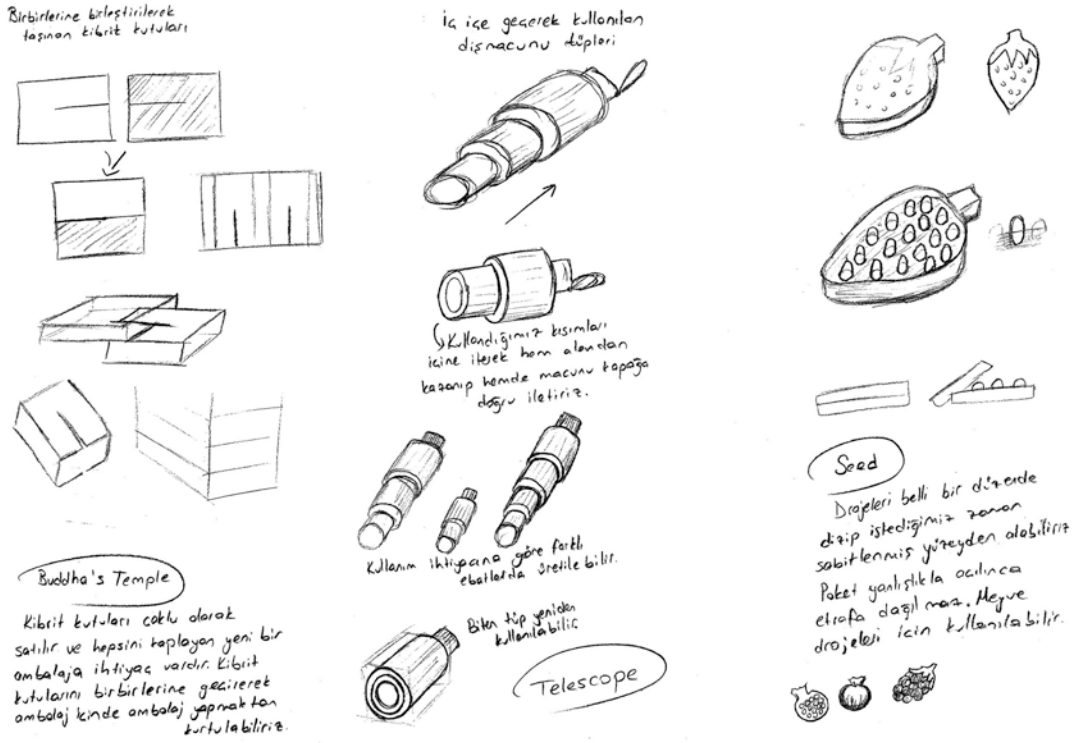



Figure 4.32 – Exercise Outcome 1 for the Second Session by Student 30

For the toothpaste package, she was influenced with the 'telescope' paradigm for a space saving tube within different sizes that can be refilled as well.

For the third brief, she proposed a form-influenced package that contains the dragees within a seed-like formation. The ordered pack is formed as fruits of specific flavours, such as strawberry and grape. In addition to this concept, she generated an

idea with sustainable concerns as well. Inspired by the clamshell, she proposed a hinged dragee pack that can be used as a paper clip or with similar purposes in its post-use (Figure 4.33).

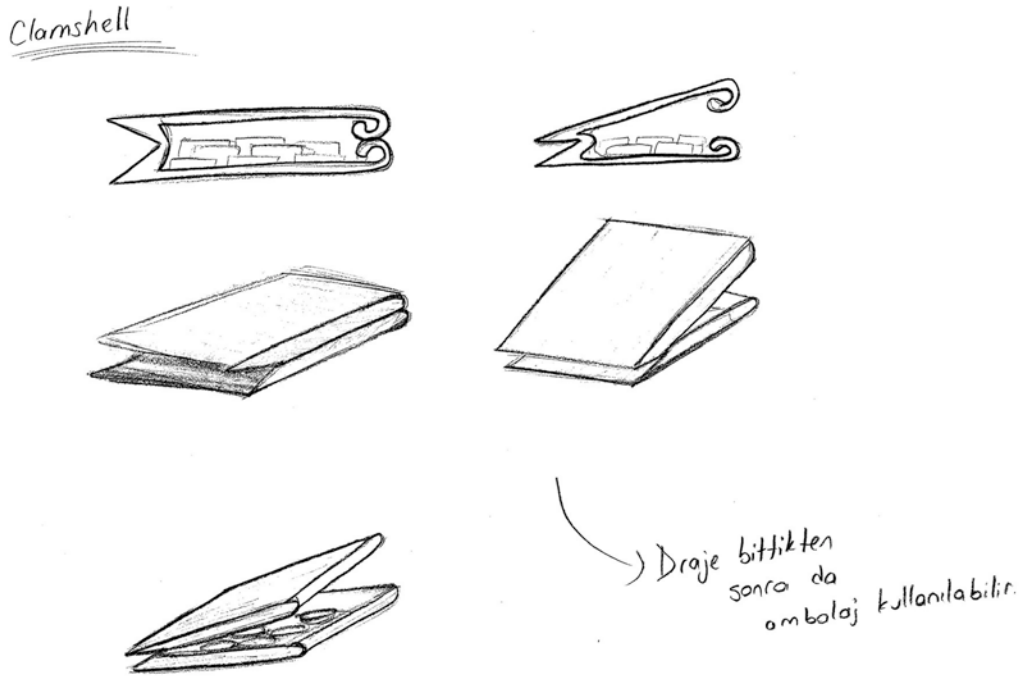



Figure 4.33 – Exercise Outcome 2 for the Second Session by Student 30

Through the exercise, Student 30 focused on a singular use of strategies for ideas and developed concepts that consider the use and post use of the packages as well as the form, materials and mechanisms. The outcomes show that she followed a structured way in the second session, instead of the free flow sketching approach in the first session. Although there was a decrease in the number of ideas after the multiple concepts she generated in the first section, she managed to generate new ideas for all the design problems in the second session as well.

**Results for Student 30**

The survey results that are summarised according to the content analysis categories are presented in Table 4.8.

Table 4.8 – The Categorised Results for Student 30

| | | Insights of the Student |
|---|---|---|
| NDP Card Deck Exercise | Presentation | Helped to understand considerations in design process, conveyed information through interesting visuals and keywords. |
| | Design Brief | Made us think more effectively and faster through by forcing to consider different areas and aspects. |
| | Conduct of Exercise | Individual ideation process was fine, and the group analysis allowed us to think through different perspectives. |
| Appropriation of Card Deck | Design of the Cards | Images helped to visualise paradigms, content emphasised keypoints to consider. Cards were coherent. Referred to images, examples and aims. |
| | Use of the Cards | Visualised paradigms by browsing images, examined examples, ideated. Checked the viability of ideas. Used multiple paradigms with one dominant. |
| Nature, Paradigms and Design | Nature | I noticed that I didn't refer to nature in my design process. I became curious and will be investigating it from now on. |
| | Paradigms | Paradigms were familiar, yet places of use and aims helped me gain a new perspective. Help to think of the product from a critical approach. |
| | Relation with Design | Knew about the relationship, yet didn't know it was such well connected and interrelated through paradigms. |
| Personal Assessment | Implications of Approach | Useful exercise to think of metaphors easily and design efficiently. Seeing a lot of options and principles made me think differently. |
| | Perceived Aim | To design inspiring from nature and to gain consciousness on paradigms in nature. |
| | Difficulties & Suggestions | Generally content with the exercise, felt limited in utilising paradigms and generated more solution-oriented ideas in first session. |
| | Future Use | Thinks ofusing the paradigm approach and referring to nature in future projects. |

As presented in Table, Student 30 was not satisfied with the exercise process and the outcomes as there was a decline in the ideas she generated. She stated that she found the exercise useful in terms of metaphorical thinking with a lot of options present. However, she expressed that she felt limited in utilising paradigms in design process. Though she was generally content about the theme of the exercise, she rather favoured her ideas in the first session as she thinks they were more solution-oriented. She described the aim of the exercise as to gain consciousness on paradigms from nature and to design inspiring from them. Nonetheless, she indicated that she thinks of using the paradigm approach and referring to nature in future projects.

### 4.3.7. The Overview of the Results for Student Cases

The student cases presented in this section were analysed in order to examine the way participants utilised the introduced approach and the card deck tool in their design ideation process. As mentioned earlier, the selected cases represent six different groups regarding their evaluation of their exercise process and the change in their number of ideas.

As indicated in Table, Students 33, 15, 7, 20 and 30 mentioned that the presentation provided essential knowledge on the subject. Student 1 and 30 stated that it supported the design process, and it was also added by Student 1 that the presentation provided them a critical perspective. The participants evaluated the different concepts defined in the brief positively. It was stated that the brief made them think of multiple and varied subjects simultaneously.

As for the conduct of the exercise that included a group analysis followed by an individual design process, Students 1 and 15 mentioned that the group analysis enabled to learn from others. Student 33 and 30 were content about the format and stated that an individual conduct enabled a personal reflection upon a collective analysis. Only Student 7 and 20 mentioned that they would prefer a group work in the ideation process.

The design of the cards was found coherent by the participants, yet few exceptions were mentioned by Student 15 and 7. Regarding the most used side, Student 1, 15 and 7 stated that they referred to the text side, whereas Student 33 and 20 indicated that it was the image side. Student 30 was the only one who mostly used both sides. The use of cards was occurred through a pattern of browsing, examining and selecting, and inspiring and using in designs. Only Student 30 mentioned the checking of the concept as a step that follows ideation. Student 33 stated that cards were inspected linearly, and Student 15 and 7 mentioned that they were inspected through aims, examples, keywords and images. Students 1, 33, 20 and 30 stated they used multiple paradigms and combined more than one strategy in a single design, whereas Student 15 and 7 mentioned that they used a single paradigm for each design problem.

Table 4.9 – Overall Categorised Results for the Selected Student Cases

| | | Student 1 | Student 33 | Student 15 | Student 7 | Student 20 | Student 30 |
|---|---|---|---|---|---|---|---|
| NDP Card Deck Exercise | Presentation | Supported design process<br>Provided a critical perspective | Providing essential knowledge | Providing essential knowledge | Providing essential knowledge | Providing essential knowledge | Supported design process<br>Provided essential knowledge |
| | Design Brief | Thinking of multiple problems simultaneously | Thinking of varied subjects simultaneously | Thinking of varied subjects simultaneously | Thinking of multiple and varied subjects simultaneously | Thinking of varied subjects simultaneously | Thinking of varied subjects simultaneously |
| | Conduct of Exercise | Learning from others in group analysis | Collective analysis and individual reflection | Learning from others in group analysis | Prefers group ideation | Group analysis was useful<br>Prefers group ideation | Collective analysis and individual reflection |
| Appropriation of Card Deck | Design of the Cards | Coherent design<br>Mostly used text side | Coherent design<br>Mostly used image side | Coherent design with few exceptions<br>Mostly used text side | Coherent design with few exceptions<br>Mostly used text side | Coherent design<br>Mostly used image side | Coherent design<br>Mostly used both image and text sides |
| | Use of the Cards | Browsed, Selected, derived designs. Combined multiple strategies | Inspected cards linearly<br>Combined multiple strategies | Inspected aim&examples<br>Used single paradigm for each problem | Inspected keywords and images, used single paradigm for each problem | Examined & selected cards and used in ideation<br>Used multiple paradigms | Browsed and examined cards, ideated and checked<br>Used multiple paradigms |
| Nature, Paradigms and Design | Nature | Awareness towards nature for design solutions | Awareness towards nature for design solutions | Awareness towards nature for design solutions | Awareness towards nature for design solutions | Awareness towards nature inspired design approaches | Awareness towards nature for design solutions |
| | Paradigms | Inclined to observe surroundings carefully | Awareness towards paradigms | Provided a critical perspective on objects and nature | Awareness towards paradigms | Awareness towards paradigms | Provided a critical perspective on objects and nature |
| | Relation with Design | Making further connections between things | Awareness towards associations between concepts | Awareness towards associations between concepts | Awareness towards associations between concepts | Awareness towards associations between concepts | Awareness towards associations between concepts |
| Personal Assessment | Implications of Approach | Seeing diverse Possibilities<br>Accelerated Design Process<br>Association of Concepts | Insights on Design Process<br>Foster Creative Thinking<br>Accelerated Design Process | Accelerated Design Process<br>Improvement by Variations<br>Gaining awareness | Essential Knowledge on the nature and paradigms approach in design | Introduced to a new design approach and process | Developing a critical approach, improvement by variations |
| | Perceived Aim | Creating Awareness<br>Using nature in design for improving & sustainability | Acquiring essential knowledge | Learning about nature and paradigms and reflecting to design | Creating Awareness on paradigms and design<br>Enabling a critical approach | Acquiring essential knowledge on paradigms and their use in design | Designing using nature and paradigms to gain awareness |
| | Difficulties & Suggestions | Not Enough Time | Long Duration | Not Enough Time | Not Enough Time<br>Longer time allocation or decreased number of ideas | Time limitation made pressure | Limiting to utilise paradigms |
| | Future Use | Will observe nature and use the NDP approach in future design processes | Will use the NDP approach in future design processes | Considers using the approach in future projects | Considers using the approach in future projects | Will observe nature and use the NDP approach in future design processes | Will observe nature and use the NDP approach in future design processes |

On the nature, paradigms and design, the participants mentioned several aspects. Five students stated that the exercise created awareness towards nature for deriving design solutions and Student 20 mentioned that it created awareness towards nature inspired design approaches. For paradigms, again it was stated by three students that the exercise created awareness. Students 15 and 30 mentioned that it provided a critical perspective on objects and nature. It was stated by Student 1 that the exercise led them to observe their surroundings carefully.

Regarding the relation of these subjects with design, it was mentioned that the exercise also created awareness towards the associations between these concepts. Student 1 stated that it enabled making further connecting between things.

The participants stated a number of implications as the result of the utilisation of approach in design process. They were majorly the acceleration of the design process (3 students), improvement by variations (2 students) and knowledge on the nature and paradigms approach and process (2 students). The participants also mentioned that the approach enabled them to see diverse possibilities, associate concepts, gain insights on design process and gain awareness. Additionally, it was stated that the exercise fostered creative thinking and helped to develop a critical approach.

The perceived aim of the exercise was stated as acquiring essential knowledge on paradigms and their utilisation in design (Students 33, 15, 20). Additionally, Students 1, 7 and 30, mentioned creating awareness as the aim of the exercise. It was also stated that designing with nature and paradigms was aimed with the exercise. Only Student 1 mentioned the objectives of improvement and sustainability.

The major difficulty was stated as the allocation of time by Students 1, 15, 7. It was mentioned that the time limitation made pressure (Student 20) and the long duration of the exercise posed some difficulties (Student 33). Student 7 suggested the conduct of the exercise within a longer time period or a decrease in the number of design problems. Only Student 30 mentioned that it was limiting to utilise paradigms in the design process.

For future projection, all participants stated that they consider using the approach in future projects. Student 1, 20 and 30 also mentioned that they would observe and refer to the nature in their future design processes.

### 4.4. Assessments of the Supervisor

An interview was conducted with the thesis supervisor Dr. Hakan Gürsu, who was present in the exercise as a facilitator and provided critiques through the process. His assessments regarding the integration of the approach to design ideation process are as follows.

The supervisor stated that the card deck could be an effective tool with regard to the level of experience of the target group. With the participants that have more knowledge on the design process, the tool may be helpful in enhancing the ideas, speeding up the process and increasing the number of concepts and variations. Yet, it might be misconceived and result in negative implications within an inexperienced group, as they may tend to think of design as the transferring of metaphors and perceive this approach as a formula to be practiced. Though the selected study group seemed conscious about the main focus of the exercise, it was important to emphasise the methodology of paradigms approach in design ideation process.

Additionally, it was stated that a major concern was to make participants think of the paradigms found in nature and objects to perceive how and why they are utilised as specific principles in various cases. Dr. Gürsu mentioned that nature is a school of design in terms of these solutions and should be observed and studied continuously for utmost learning. He also stated that the critical approach of paradigms might help to analyse and decode existing products and the exercise could be useful as a thought-provoking and reasoning tool within this perspective to learn about the philosophy behind these strategies. It was stated that as an introduction, the exercise could be assessed as successful, yet the necessity of a background to build upon these information into knowledge was emphasised.

The supervisor also pointed out to the improvement in outcomes of the exercise in terms of both quality and quantity that indicated the positive effect of the tool. He stated that the exercise was also beneficial in providing a general framework on nature inspired design, which the participants lacked knowledge of. Dr. Gürsu elaborated on the structure of the process and mentioned that the stages were coherent and the participants adopted the tool comfortably.

He further expressed that the group analysis followed by an individual design ideation was proper for the purpose of the exercise. However, he agreed with the participants on the time allocation and suggested a longer period for further studies. Another aspect to be inquired in future was addressed as the selection of subjects other than packaging. According to the supervisor, the tool could be used through a period of time and the projects or design brief could range from simple to advanced within several steps in which complexity and density increase. Therefore, the approach whose effects could be observed through a brief exercise could be implemented within different fields in design education throughout the process of a design project.

## 4.5. Overall Results of the Research

In this section the results of the primary research are presented regarding the nature design paradigms approach and its incorporation in design process.

### Insights on Participants

The research showed that the second year industrial design students were generally aware of the nature inspired design, however ‘inspiring from nature’ is a vague concept and is open to misinterpretations. The examples they provided points that the knowledge on the subject was lacking dimensions or even worse, there were misconceptions about the approach. Nearly all participants (35 out of 39) stated they tried to inspire from nature in their design process, as the instructors generally suggested it. However, research results indicated that the students do not have the knowledge and tools to incorporate the approach. In addition, it was seen that their

previous practices with nature in design process were mainly focused on form studies; therefore they did not have a comprehensive picture on the approach and the possibilities it may offer for design.

The other critique factor regarding the students was their level of experience in design. As the exercise was formed as an ideation workshop, the abilities of thinking by sketching and communicating ideas quickly were important assets, yet posed limitations for some of the participants. Also, the understanding of the design process and its stages influenced the process. The students needed guidance throughout the exercise and facilitators provided assistance through workshop sessions.

### The Exercise Process

The presentation prepared to equip the participants with introductory knowledge on subject was found helpful as it provided a general framework and examples of applications. Through supplying information on nature inspired design, its levels and methods, this session eliminated the lack of knowledge regarding the subject that is mentioned above. Also conveying a background on the design paradigms and packaging design, the presentation helped to build a foundation on the subjects and communicated the considerations that exist within the area.

The session that followed included a group analysis of the packages from nature and industrial products that are collected by participants. This phase enabled the participants to assess the packages from a critical approach and to think about the strategies employed in them. As the discussion was carried out, the context of the products were inquired along with the identification of problems and needs. The collective conduct allowed to hear thoughts from different perspectives and to learn from the participants and the facilitators. The analysis session assisted the participants to leap from observation to action and affected the ideas and concepts created in the next session through defining the problem space.

The idea generation session was carried out in two sequences, in the first round, the participants developed packaging concepts without inspiring from nature and

objects. On the other hand, the second round incorporated a card based tool -the NDP Card Deck - developed to utilise nature and human strategies in design process. The design brief included three concepts - dragee pack, toothpaste package and matchstick package - to generate ideas on, therefore the participants were expected to develop six concepts in total, whereas they could add more ideas if they have. Regarding the number of ideas, 11 students had increase and 8 students had decrease in the concepts they generated, and the remaining 21 students had the same number of solutions. The participants were content about the approach in general, however their evaluation of their design process and outcomes were also divided into three groups as negative, neutral and positive assessments. The participants who assessed their ideas and process negative had either difficulties in using the card deck or were not satisfied by their performance. The participants that had a neutral opinion were content about the exercise, yet evaluated their ideas as basic concept that requires further refinement. The third group of participants assessed the process and their ideas positive as they found the exercise favourable in enhancing their design process.

The second year students have difficulties in the early phase of the design process and they seek guidance in identifying the context for problem and solution space. In this sense, the exercise provided a basis in analysing, defining and ideating phases within product design problem solving. The participants stated that they gained insights on design process and realised the wide range of possibilities that are available in the initial stage of the design.

In terms of the idea generation session, the students were not familiar with a fast paced brainstorming and ideation process and it was their first experience of working in with a time limit. Though the exercise was compelling, they managed to create multiple design solutions within a short amount of time. For the comparison of the two ideation sessions, the outcomes show that the incorporation of the card deck tool flexed their capabilities for alternating between solutions, accelerated and enhanced their process.

The inspection of the developed ideas and concepts indicates that the participants were able to go beyond the form practices and derived solutions in various

dimensions including form, function and materials. The exercise also nurtured their ability of metaphorical thinking and using analogies. However, the participants were inevitably influenced by the design briefs and employed similar strategies within different concepts on occasion. On the other hand, the utilisation of strategies illustrated that the ideas employed mainly paradigm transfers that change the way things work, rather than paradigm shifts that redefine the way they are in an innovative manner. However, this would require an advanced level of implementation with the allocation of a more experienced group and more time.

The research revealed a correlation between the ability to generate a variety of paradigms and the number of ideas and variations both in the preliminary and primary studies. In the preliminary research, the answers to design paradigms related questions showed that the participants who could develop multiple alternatives were likely to use metaphors. Therefore, the number of variations increased with the use of analogies and paradigms. The primary research also demonstrated that the participants who used multiple paradigms in a single concept were able to either generate a single concept for each brief or increase the number of ideas they develop within the second round. Though this issue points to a relation between these aspects, the topic needs further research and clarification to suggest more clear associations.

The majority of the participants (33 out of 40) found the group analysis followed by an individual ideation process favourable, however there were few participants who suggested group work in the idea generation session as well, at least for one design problem. The main difficulty, on the other hand, was addressed as time allocation for the concepts, which was not found enough by a large part of the participants (26 out of 40). The participants proposed a longer period of time, such as a weekend, to enable a less overwhelming process.

### Inferences Regarding the NDP Card Deck Tool

The Nature Design Paradigms Card Deck was found useful as a practical tool to employ the paradigm approach and the strategies from nature and human designs in design ideation process. The design of the cards was stated as coherent and simple to

understand, relate and utilise with few exceptions that were described as abstract. The participants expressed that the visual side and the images were inspirational to derive solutions for form and mechanism, whereas the explanation side was helpful in defining functions, purposes and objectives.

The way participants described how they used the cards in their design process exposed a repeating pattern of design model. The cycle of use was consisted of four steps: overview, elaborate, inspire and implement. As mentioned earlier, the process overlapped with the expected model of use of the card deck within the idea generation and problem solving phase.

The language of the cards posed a difficulty for a group of participants (16 out of 39) and few participants (7 out of 39) mentioned that they would prefer the cards in Turkish even though they did not have any problems relating to the language. The remaining part of the participants (16 out of 39) were content about the language, moreover some of them suggested that it was beneficial for becoming familiar with the professional lingo.

**Personal Assessments**

The aim of the exercise was perceived as creating awareness on nature, conveying a critical perspective on design paradigms, associating nature, paradigms and design and gaining insights on design process. The exercise aimed for these objectives as well, however its major aim was to integrate the nature design paradigms approach in design process to explore the effects of the utilisation of its strategies in idea generation process.

As referred to in the perceived aim of the exercise, the approach helped participants in gaining consciousness towards nature and paradigms and encouraged them to associate these concepts from a critical perspective regarding product design. All participants stated they would observe the nature and their surroundings more carefully and look out for design solutions to derive. And 37 out of 40 participants mentioned that they consider using the paradigm approach in future projects. Although the participants were in favour of the approach in general, their

assessments on their performances were divided into three groups including positive (10 students), neutral (19 students) and negative (11 students) impressions. The participants indicated some key points regarding the implications of the exercise. They found the exercise useful for the following reasons:

- Developing a critical approach
- Accelerating the design process
- Improving the quality and the quantity of ideas
- Associating nature, paradigms and design

On the other hand, they mentioned some difficulties regarding the conduct of the exercise and the utilisation of the tool that are as follows:

- Allocation of time
- Duration of the exercise
- Difficulties in interpreting and emulating the strategies

This chapter presented the analysis of the evaluation results with the participants and the outcomes of the exercise in detail to illustrate the implications of the integration of the nature design paradigms approach into the design ideation process. In the next chapter, the conclusions of the research are discussed.

# CHAPTER 5

# CONCLUSIONS

This chapter presents the conclusions of the study through revisiting the research questions and includes the implications of the findings on the idea generation exercise process and further research.

## 5.1. Research Questions Revisited

**How can a strategic tool that utilise nature and design paradigms for enhancing and supporting idea generation be developed to inspire the idea generation phase and what would be the implications of the integration of this methodology into the design process?**

Within the process of this thesis study, abovementioned subjects were explored in detail and the ways to employ these strategies in idea generation phase were investigated. Paradigms and principles were indexed, overlapped and combined to compile a list of strategies to inspire the design process. As the study aimed at the integration of the approach and the investigation of its effects, it was necessary to conduct a field study using these strategies. An exercise in the form of a workshop was found useful for this purpose; however, in the initial stages the method for applying this approach was unspecific. A variety of ways were considered to convey the paradigms to the target group and through the process it was found beneficial to develop a tool in the form of method cards that could be utilised in the design practice. Nonetheless, it should be mentioned that within the study, the objective was the exploration of the utilisation of the approach and the developed card deck tool was a means to achieve this goal.

The integration of the approach affected the participants' design process and outcomes positively in general through accelerating and flexing the ideation phase. The exercise enabled an improvement in idea generation by illustrating a wide range of solutions and assisting in creating alternatives and variations on themes. Though the participants were not accustomed to a rapid process of brainstorming, they were able to develop several ideas in a short amount of time. This result indicates the effectiveness of the card deck tool in design process as it was formed to support the design ideation and metaphorical thinking. Therefore, the NDP Card Deck was found useful as a tangible strategy source that provides inspiration through images and objectives.

Moreover, the study findings suggest a correlation between the use of metaphors/paradigms and the number of generated ideas. Both preliminary and primary research point that the ability to perceive and utilise metaphors in design affects the number of design solutions in a positive way. The participants who were able to develop several variations of concepts on an increasing number were also able to transfer and use multiple paradigms from nature and objects. Yet, it should be noted that this issue needs further clarification through future studies.

In spite of the fact that the participants were previously utilising the nature inspiration in a form-based manner in general, through the exercise they were able to derive design ideas on various levels such as form, function and materials. However, the outcomes show that the strategies were generally replaced through ideas and the ideas present the incorporation of paradigms as transfers, rather than paradigm shifts that redefine the problem. To obtain more innovative results, the shifting of paradigms could be emphasised within the exercise, yet it would necessitate a more experienced group with a narrowed brief preferably on a single subject.

The exercise was found beneficial as it delivers insights on the design process as well. Besides being an inspirational tool for idea generation, the approach introduced an alternative design process and thinking with the utilisation of paradigms method. The participants experienced the concept generation phase within a practical session and suggested several solutions for defined problems. Therefore, instead of focusing directly on a specific solution, they observed the divergence in ideation stage that

will converge towards a final design. Thus, the tool assists the participants in developing an iterative approach within the design process, instead of being merely a card deck to choose and assign strategies from.

The approach was integrated into design process through a workshop exercise that consists of a presentation on the subject, group analysis on the product examples from the specified field and the idea generation session. The analysis of the participants' use of the cards revealed a pattern that is in accordance with the process expected in the integration model. The design cycle of the NDP Card Deck tool includes four steps - overview, elaborate, inspire, implement - that correspond to the problem solving process with the additional analysis and evaluation sessions. In addition, the participants indicated that the utilisation of the cards in the exercise was clear and intuitive. Therefore, the integration and implementation of the method within the design process could be considered successful regarding this objective.

**How would the implementation of this approach within design process effect the designers' perception on nature, design paradigms and their relation with design as problem solving models and strategies?**

As the perceived aim of the exercise indicated, the utilisation of the approach in design process affected the perception of participants towards nature, design paradigms and their relations to design. The exercise, first of all, created awareness on nature and the possibilities it holds for industrial design. Through the presentation and group discussion, the participants realised the nature influence on products. Also, with the introduction of design paradigms concept, they became more conscious on the strategies that are present in our daily lives. The participants stated that the exercise helped them to develop a critical approach towards their environments and provided them with the new perspective of paradigmatic thinking.

The second major influence of the exercise was enabling the association between concepts by revealing the links through examples employing similar strategies. Though they were generally familiar with the paradigms and their incorporations, the participants were mainly unaware of the extent of this relationship and were intrigued by the discovery of the interrelated structure of solutions. It was also stated

that the introduction of these connections led them to create new links between nature, objects and designs and made them question the origins of these strategies and metaphors. Therefore, in general, the participants indicated that they would observe their surroundings more carefully in the future to build a personal glossary of paradigms to be employed in design solutions. The paradigm approach was embraced by the majority of the participants (37 out of 40) who stated they would use it for analysing nature and products and in generating ideas in their design process.

**What are the considerations and aspects in integrating nature and design paradigms approach as a tool into idea generation phase and how do designers respond to this process in terms of outcomes and evaluations?**

From the specification of brief to the selection of strategies in the card deck, there are several aspects to be considered in integrating a card-based tool with the proposed approach. As the research is focused on the packaging design for its field study, the strategies were shaped around the basic paradigms that can be utilised for diverse purposes within various mediums. The design of the cards was intended to be comprehensible and inspirational with the images, examples and aims and according the participants' assessments, the tool achieved this point.

Another important aspect was the preparation of the presentation to provide fundamental knowledge on the subjects that the participants lack. Besides introducing the concepts of nature inspired design and design paradigms, the presentation informed the audience on focuses and considerations of packaging design. Through a variety of examples that illustrate the ways to employ nature and human strategies, the participants gained consciousness on the applications and benefits of the approach.

The outline and the conduct of the workshop posed a key factor within the research. The stages, duration and content of the exercise were prepared elaborately with the received feedback from the pilot workshop. The number and variety of concepts were specified with their complexity and potential solution space in regard. According to the survey results, the participants found the diversity in the brief

favourable and indicated that it led them to think of different fields, contexts and requirements. The individual conduct of the exercise with a group analysis prior to idea development stage constituted a dimension to be examined. As the workshop was structured as a one day program with limited time allocation, the practical session was conducted as an individual process. The participants majorly evaluated this aspect positive, stating that the collective analysis enabled to learn from others' perspective, whereas the ideation session built upon that step as personal reflection. However, a group work may provide a more educative process and could be further investigated in future projects to assess its dynamics and the outcomes.

From the participants' point of view, the process presented some challenges as well. As the research is aimed to assess both the advantages and disadvantages of the approach, the outcomes and evaluations of the participants were analysed to explore the effects of the exercise on their design process. One of the main findings point that the students lack knowledge on the nature inspired design concept, furthermore the preliminary research showed that there were some misconceptions about the subject. In this sense, the presentation provided the essential information on nature, paradigms, their relation to design and the possibilities they hold for packaging. The participants expressed that the presentation was helpful in constituting a framework to later generate ideas that incorporate the approach.

A major challenging aspect, on the other hand, was the students' inexperience in design process, the brainstorming and ideation sessions in particular. The research results indicate that the second year students need guidance in the design process, especially in the beginning of the projects where the context defining and solution finding phases take place. The exercise provided a first hand experience in design ideation through analysing the products, identifying problems and developing concepts. The participants mentioned that they gained insights on design process through the exercise as well.

The participants were generally content with the approach and its implications for design. A major part of them (29 out of 40) were also content about their ideation process within the exercise. As the productivity in brainstorming process had a positive effect, the participants might have favoured the process itself, regardless of

the quality of their ideas. Consequently, this aspect suggests that the exercise encourages the participants throughout the design process.

In terms of the card deck, the participants found the design and the use of the cards clear and mainly expressed that the images, paradigms and content matched in a coherent manner. However, the language of the cards presented difficulties and more than the half of the participants stated they would prefer it in their native language. Apart from these, the participants faced challenges regarding the utilisation of the strategies to derive design solutions. A few participants stated that they felt limited in employing specific solutions in ideation process. Also, it was mentioned that some cards were difficult to interpret or associate with the design brief. This may due to the intangible nature of some paradigms such as ‘tree’ or ‘cluster’. The time pressure and the lack of experience could be another reason of this problem, which can be further investigated with a variety of sample groups.

The process also posed difficulties in terms of time limitation and overall duration. The participants highlighted that it would be preferable to have more time or less number of concepts as the workshop was a fast paced and compelling exercise. Another suggestion was to have a longer period of time for the workshop, such as splitting the program into two days. Since the workshop was an independent exercise from studio projects, it was structured as an idea generating session comprised of quick sessions for ideating and sketching. However, a more comprehensive workshop outline could be devised and integrated into a design project as well for further studies.

To conclude, the Nature Design Paradigms Card Deck exercise can be incorporated within the early phases of the design process to support idea generation and encourage the participants in developing concepts through paradigms thinking. As the supervisor stated, above a certain level, it constitutes a tool for the designers to enhance their ideation process and develop a critical perspective on nature, objects, products and strategies embodied within these systems. The utilisation of the approach in the design process could be explored further and the application of the tool could be investigated within different contexts in terms of target group, exercise format and design brief.

## 5.2. Implications of This Research for Improving the Exercise

The exercise was conducted among design students, whose experience and capabilities in design process were the main determinants of the study outcomes. Although 35 out of 39 participants stated that they did get inspired from nature in the preliminary survey, their notion of 'nature inspired design' was mostly lacking or misconceived. Therefore, the exercise firstly provided knowledge on the subject with the presentation to show the ways to derive solutions from nature and manmade paradigms. Unlike the card deck, the examples within the presentation were mainly focused on packaging products. In future uses, it could be specialised for the selected project brief or area. However, in contrast to the converged overview, a generalist approach could also be followed to convey more comprehensive knowledge on the subject through examples selected from diverse fields.

The second session included the group analysis part, where nature and manmade packages selected by participants were analysed and the strategies they employ were discussed. This part was found especially helpful as it enabled a transition from theory to practice and allowed participants to speculate on the products, their context, problems and needs. However, the exercise was not context-specific such as designing for accessibility. Although the focuses of sustainability and innovation were introduced to the participants as exemplary spaces for improvement, the exercise was rather short spanned for achieving these concerns. Few participants submitted concepts with sustainability approach, however, it cannot be stated that the exercise had particular emphasis regarding these focuses. Such concerns could be incorporated in the design process within the analysis session and the assessment of the product examples could be made through that perspective.

Before being given the card deck tool consisting of predefined paradigms, with a little direction, the participants were able to observe and generate a set of strategies. For further improvement of the approach, the analysis phase could be implemented as an assignment and the participants could be allocated to identify and examine paradigms shared by nature and objects. This practice may help in learning to derive paradigms from their origins and employing the approach as a tool for tool making.

Thus, beyond the idea generation tool, the approach could be absorbed as a method of thinking, as the supervisor suggested.

In the third session, the participants developed ideas and concepts first without, then with the use of the card deck tool for inspiration. Although each student interpreted the paradigms in the card deck in their own way, the strategies they utilised were limited to the same source. As the participants were inexperienced in design process and lacked knowledge on the subject, this method was found appropriate. On the other hand, the process could be liberalised in further implementations of the exercise, such as multiple sessions throughout a project, and could be carried out with an emphasis on the paradigmatic thinking, where participants may define and use strategies that are not represented in the deck. In other words, the NDP Card Deck tool could be utilised as a step in a longer period that is designed to employ the paradigm approach. This model also might be more effective in investigating the effects of the approach throughout a total design process and it may reveal further implications to analyse.

As the exercise was a fast paced process, it did not include a discussion and evaluation of the ideas generated through the ideation sessions. Such a step could increase the engagement of the participants and enhance the learning and inspiring from others. An implementation within a larger schedule may allow conducting this phase as well. Furthermore, the formation of the exercise could be changed to a group work to examine the dynamics of an ideation that is closer to a brainstorming session.

Regarding the outcomes, it can be observed that the participants had focuses of form and function that referred to as the first level or reductionist approach in inspiring from nature. This may due to a couple of reasons: the participants were new on the subject, the exercise had a short time limit and the packaging was mainly associated with objects rather than processes and systems. Similarly, the use of paradigms were in form of transfers, instead of paradigm shifts that transform the problem and evolve the solution into a new level. In addition to the factors above, the exercise could be limited with a single design brief or project for a concentrated design process. As the pilot workshop results showed, the exercise could be more effective

with a relatively experienced group – junior and senior design students – who were able to develop creative concepts within the allocated time. In order to obtain more refined results, these issues may be further studied by altering these aspects and conditions.

For the process of utilising the card deck, a general pattern was revealed. However, a more in depth analysis could be made on the inspiring from the cards. In order to achieve this, a thorough observation through the idea generation process would be helpful, as well as the interviews with the participants. The way images and purposes inspire the product ideas could be investigated in detail. Thus, further studies may reveal individual processes on leaping from the inspiration to the design idea.

Another aspect for improvement was raised on the structure of the cards. The NDP Card Deck was designed as a tangible, hands-on tool to be incorporated in design process and the feedback from the participants showed that the physicality of tool was favoured. Yet, there is space for innovation in the digital field and as the comments illustrated, the participants needed a 'search bar' where they can classify the cards according to data sets. The paradigms, images and examples could also be extended within digital platforms, such as mobile or web-based applications. Therefore, a more accessible tool that regularly updates could be build. As the tool is still in development stage, the card deck could be further improved.

### 5.3. Implications for Further Research

The thesis points out two major directions for further research in terms of the utilisation of nature and design paradigms approach and the card deck tool in design process. As mentioned above, the approach would have the potential to be incorporated in a design project within design education or practice to explore its implications through an overall product design and development process. The NDP Card Deck could be used at a specific stage in this process, whereas the other stages require developing as well. The second issue that is worth examining is the selected area of products. The packaging design was specified as a focus in this study, since

its level of complexity is relatively lower compared to the areas as home appliances or electronics. The integration of the approach into such fields with different considerations could be investigated. Furthermore, the product categories that pose less restriction are also available, such as furniture design or promotional products.

As the design education and its dynamics are constantly changing, the need for various methodologies that could be utilised in the design process is increasing. Approaches that enable synthesising diverse knowledge from different fields, not only introduce different perspectives, but would provide acceleration in learning. In this sense, the investigation of the approaches that could support the ideation phase in product design, may lead to the development of useful tools and methods for designers, researchers and educators.

## REFERENCES


Altshuller, G. (1994). And Suddenly the Inventor Appeared. Technical Innovation Center, Worcester, MA.

AskNature.org (n.d.) Vitalis Water Bottle. Retrieved on June 1, 2014, from: http://www.asknature.org/product/b5dc4030c48e41b03442d34aecdf46b4

AskNature.org (n.d.) The Biomimicry Taxonomy: Biology Organized by Function. Retrieved on June 1, 2014, from http://www.asknature.org/article/view/biomimicry_taxonomy

Ayres, L. (2008). Thematic coding and analysis. In L. Given (Ed.), *The SAGE encyclopedia of qualitative research methods*. (pp. 868-869). Thousand Oaks, CA: SAGE Publications, Inc. doi: http://dx.doi.org/10.4135/9781412963909.n451

Bakırlıoğlu, Y. (2012). *Biomimicry For Sustainability: An Educational Project In Sustainable Product Design.* MSc. Thesis. Middle East Technical University, Ankara, Turkey. Dissertations & Theses: Full Text.

Ball, P. (2013). *Curiosity: How Science Became Interested in Everything*. University of Chicago Press.

Bar-Cohen, Y. (2011). *Biomimetics: Nature-Based Innovation*. Boca Raton, FL: CRC Press.

Benyus, J. M. (1997). *Biomimicry: Innovation inspired by nature*. New York: Perennial.

Benyus, J. M. (2009). Janine Benyus: 12 Sustainable design ideas from nature. [Video file]. Retrieved on June 1, 2014, from: http://www.ted.com/talks/janine_benyus_shares_nature_s_designs

Benyus, J. (2011). Lets Discuss It With. Ternaux, E. (Eds.) *Industry of Nature*. (p. 33 - 41) Amsterdam: Frame.

Benyus, J. M. (n.d.) Conversation with Janine. Retrieved on June 1, 2014, from: http://biomimicry.net/about/biomimicry/conversation-with-janine/

Biomimicry Thinking (n.d.) Retrieved on June 1, 2014, from http://biomimicry.net/about/biomimicry/biomimicry-designlens/biomimicry-thinking/

da Vinci, L. (1883/1970) *The Notebooks of Leonardo da Vinci*, Vol. II. New York: Dover Publications, 1970, 1883

de Bono, E. (1990). *Six Thinking Hats, 2nd edition*. Harmondsworth, UK: Pelican

Dawes, C. (2009). Designing packs as nature intended. *Packaging News, October 2009*, p. 28

Calver, G. (2004). *What is packaging design?*. Hove: RotoVision

Capsule (2008). Design Matters: Packaging 01: An Essential Primer for Today's Competitive Market. London: Rockport Publishers

Colorado State University, (n.d.). Writing at CSU Writing Guide: Content Analysis [PDF document]. Retrieved from http://writing.colostate.edu/guides/pdfs/guide61.pdf

Cross, N. (2004). Expertise in design: an overview. *Design Studies 25(5), 427–441*

DTI Global Watch Mission Report. (2007). Biomimetics: strategies for product design inspired by nature. [PDF document]. Retrieved from: http://www.catedrasimonetti.com.ar/attachments/278_Biomimetics%20report%20final%20version[1].pdf

Eckert, C. & Stacey, M. (2000). *Sources of inspiration: a language of design*. Design Studies 21, 523–538

Gelli, F. (2011). Lets Discuss It With. Ternaux, E. (Eds.) *Industry of Nature*. (p. 251 - 253) Amsterdam: Frame.

Gordon, W. J. J. (1961). *Synectics: The Development of Creative Capacity.* New York: Harper & Brothers

Guest, G. S., MacQueen, K. M. & Namey, E. E. (2012). *Applied thematic analysis*. Thousand Oaks, California: Sage Publications

Gürsu, H. (2012, February). Hakan Gürsu: Revival of Trash [Video file]. Retrieved from http://tedxtalks.ted.com/video/Atklarn-Dirilii-Hakan-Grsu-at-T;search%3Ahakan

Hiskey, D. (2012). Velcro Was Modeled After Burrs of the Burdock Plant that Stuck to Velcro's Inventor's Pants After a Hunting Trip. Retrieved on June 1, 2014, from: http://www.todayifoundout.com/index.php/2011/09/velcro-was-modeled-after-burrs-of-the-burdock-plant-that-stuck-to-velcros-inventors-pants-after-a-hunting-trip/

Hoyos, C. A. M. (2010). *Bio-ID4S: Biomimicry in Industrial Design for Sustainability*. Saarbrücken: VDM Publishing.

Kelley, T. & Littman, J. (2005). *The Ten Faces of Innovation*. New York: Currency / Doubleday

Kwon, E. & Fraiser-Scott, K. (2012). Walk, Feel, Think, and Make: Creative Design Learning with Nature. *DRS Conference 2012 Bangkok Proceedings*.

Lockton, D. (2014). Tools for ideation and problem solving: Part 1. Retrieved from http://architectures.danlockton.co.uk/2014/04/22/tools-for-ideation-and-problem-solving-part-1/

Macey, S. (2009). *H-Point: The Fundamentals of Car Design & Packaging*. Culver City, CA: Design Studio Press.

Macnab, M. (2012). *Design by Nature*. Berkeley: New Riders

McGee, T. (2009). Nature as model, measure and mentor. Retrieved on June 1, 2014, from: http://www.packagedesignmag.com/content/nature-model-measure-and-mentor

McGee, T. (2013). The Packaging Genius of Nature. *In: A Perspective on Global Packaging by DOW, Issue 1, 2013,* p. 24-27, Retrieved from: https://www.dow-k2013.com/web/2013/assets/misc/in_perspective.pdf

Merritt, T. & Wölfel, C. (2013). *Method card design dimensions: a survey of card-based design tools*. Paper presented at Interact 2013, Capetown, South Africa.

Myers, W. (2012). *Bio Design: Nature + Science + Creativity*. London: Thames and Hudson

Papanek, V. (1985). *Design for the real world: human ecology and social change* (2nd Ed.). Chicago: Academy Chicago.

Paradigm. (n.d.). In *Merriam-Webster's online dictionary* (11th ed.). Retrieved from http://www.m-w.com/dictionary/paradigm

Petrina, S. (2006). *Advanced Teaching Methods for the Technology Classroom*. London: Information Science Publishing

Reap, J., Baumeister, D., Bras, B. (2005). Holism, biomimicry and sustainable engineering. In: *Proceedings of IMECE2005, 2005 ASME International Mechanical Engineering Conference and Exposition*, Orlando, USA, November 5–11, 2005.

Saffer, D. (2005). *The Role of Metaphor in Interaction Design*. Master's thesis, Carnegie Mellon University.

Seelig, T. (2009). *What I Wish I Knew When I Was 20: A Crash Course on Making Your Place in the World*. New York: HarperOne

Stacey, M., Eckert, C. & Earl, C. (2009). From Ronchamp by Sledge: On the Pragmatics of Object References. In McDonnell, J & Lloyd, P (eds) *About: Designing: Analysing Design Meetings.* (p. 361–379) Leiden: CRC Press

Suarez, R. (2012). A simple slide I use to illustrate how biomimicry. Retrieved from http://www.biomimicrist.com/post/17997621963/a-simple-slide-i-use-to-illustrate-how-biomimicry

Suri, J. F. (2013). The Packaging Genius of Nature. *In: A Perspective on Global Packaging by DOW, Issue 1, 2013,* p. 24-27, Retrieved from: https://www.dow-k2013.com/web/2013/assets/misc/in_perspective.pdf

Ternaux, J. P. (2011). Historical Essay on Biomimetics. Ternaux, E. (Eds.) *Industry of Nature*. (p. 15 - 31) Amsterdam: Frame.

Tseng, I., Moss, J., Cagan, J. & Kotovsky, K. (2008). The role of timing and analogical similarity in the stimulation of idea generation in design. *Design Studies, 29, 203–221*

Twede, D. (2005). The Origins of Paper Based Packaging. *Conference on Historical Analysis & Research in Marketing Proceedings* 12: 288–300 [289].

Van der Ryn, S. (2005). *Design for Life: The Architecture of Sim Van der Ryn*. Layton, UT: Gibbs Smith

Volstad, N. L., & Boks, C. (2012). *On the use of Biomimicry as a Useful Tool for the Industrial Designer*. Sustainable Development, 20, 189-199.

Wake, W. K. (2000). *Design paradigms: a sourcebook for creative visualization*. New York: Wiley

Wallentin, L. (2013). We need more packaging, not less. *In: A Perspective on Global Packaging by DOW, Issue 1, 2013,* p. 10-11, Retrieved from: https://www.dow-k2013.com/web/2013/assets/misc/in_perspective.pdf

Weber, R. J. (1993). *Forks, Phonographs, and Hot Air Balloons: A Field Guide to Inventive Thinking.* London: Oxford University Press

# APPENDIX A

## PILOT SURVEY PARTICIPANT PROFILE

Table A.1 – Pilot Survey Participant Profile

| School / Year | 2nd | 3rd | 4th | Total |
|---|---|---|---|---|
| Anadolu University | - | - | 3 Students | 3 Students |
| Arel University | 1 Student | - | - | 1 Student |
| Bahçeşehir Uni. | - | 2 Students | - | 2 Students |
| Doğuş University | 1 Student | - | - | 1 Student |
| Işık University | - | 1 Student | - | 1 Student |
| İstanbul Techical Uni. | 4 Students | 8 Students | 6 Students | 18 Students |
| Kadir Has Uni. | 5 Students | 3 Students | - | 8 Students |
| Marmara University | 2 Students | 3 Students | - | 5 Students |
| Middle East Tech. Uni. | - | 3 Students | 5 Students | 8 Students |
| Mimar Sinan Uni. | - | 3 Students | - | 3 Students |
| TOBB University | 1 Student | - | - | 1 Student |
| Yeditepe University | - | - | 3 Students | 3 Students |
| Total | 14 Students | 23 Students | 17 Students | **54 Students** |

# APPENDIX B

## PRELIMINARY SURVEY QUESTIONS

This survey was prepared as a preliminary study for a Master's Thesis at METU Industrial Design Department. The personal information provided by the participants will not be shared with the third parties under any circumstances. Thank you for your contribution.

Name Surname : .....
School, Department, Year : .....
E-mail : .....

**1. Do you inspire from nature in your design process? If so, could you exemplify?**

.....
.....
.....

**2. Do you know of any approach or method that is focused on nature inspired design as a discipline? If so, please explain.**

.....
.....
.....

**3. Could you name any examples of nature inspired design?**

.....
.....
.....

**4. Please check the words you find relevant to nature inspired design.**

| | | | | | |
|---|---|---|---|---|---|
| User | ☐ | Function | ☐ | System | ☐ |
| Form | ☐ | Process | ☐ | Biology | ☐ |
| Materials | ☐ | Innovation | ☐ | Structure | ☐ |
| Sustainability | ☐ | Energy | ☐ | Manufacturing Techniques | ☐ |

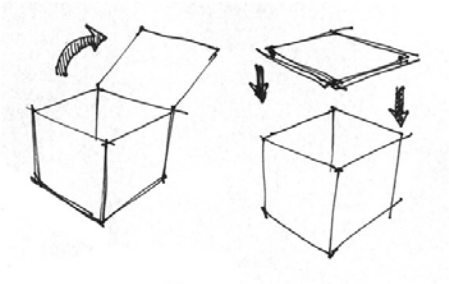


Figure 1

*Essential solutions including basic forms, functional relationships and behaviours that embody fundamental design strategies are called 'design paradigms'. Being a collection of a thousand different great little ideas, they constitute the basic building blocks of design (Wake, 2000).*

**5. In this sense, a number of ways can be used to make an object open/closed. For example, a hinge or a snap fit detail can be employed (Fig. 1). What else can be applied to achieve that aim?**

(You can communicate your ideas using written or visual expression)

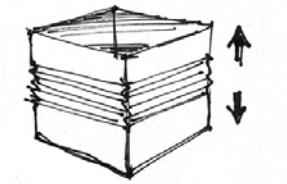


Figure 2

**6. An object can change shape and size through use of bellows (Fig. 2). Which techniques can you think of to make objects change shape/size?**

(You can communicate your ideas using written or visual expression)

## APPENDIX C

## NATURE DESIGN PARADIGMS CARD DECK

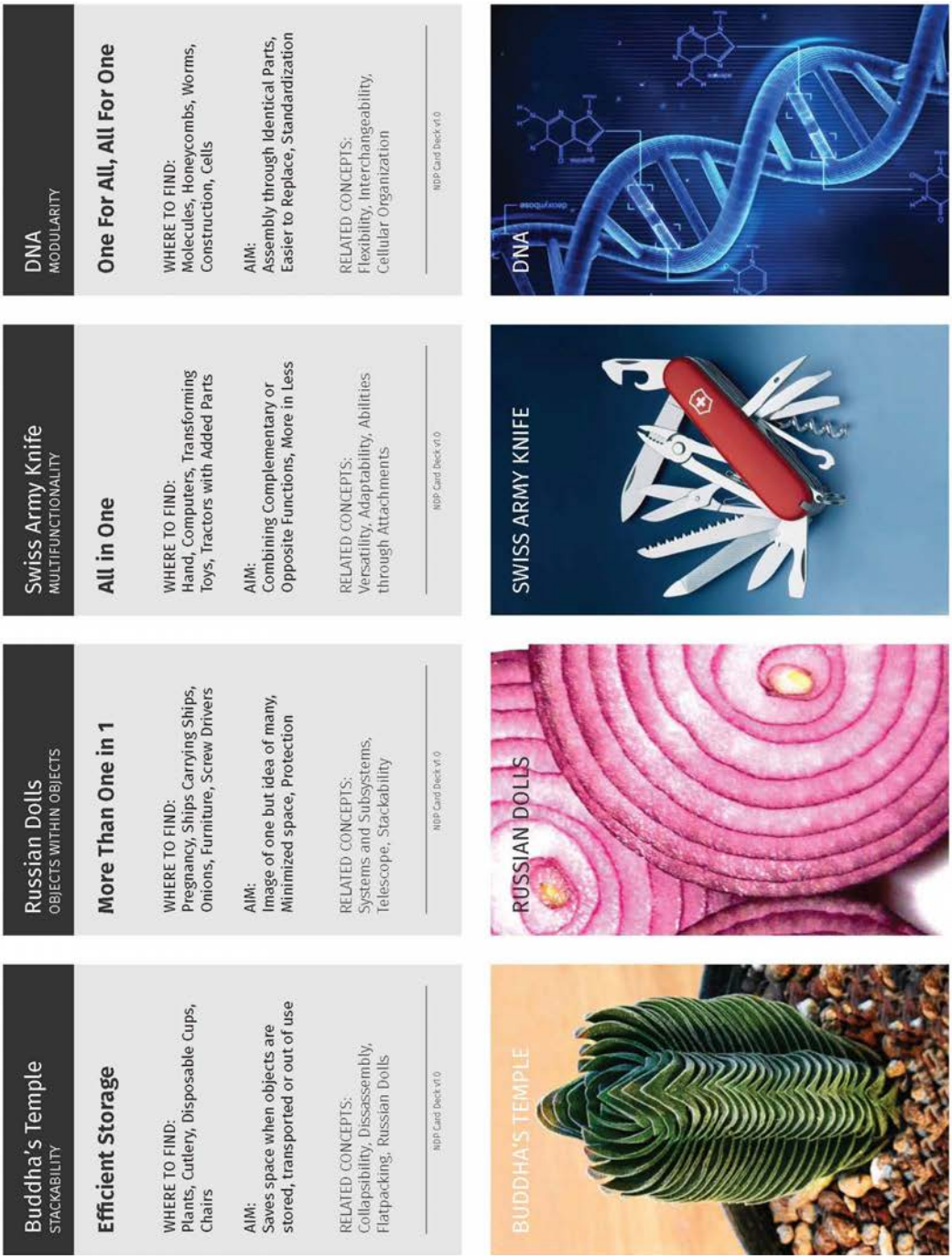



Figure C.1 – Nature Design Paradigms Card Deck

Figure C.1 – Nature Design Paradigms Card Deck (continued)

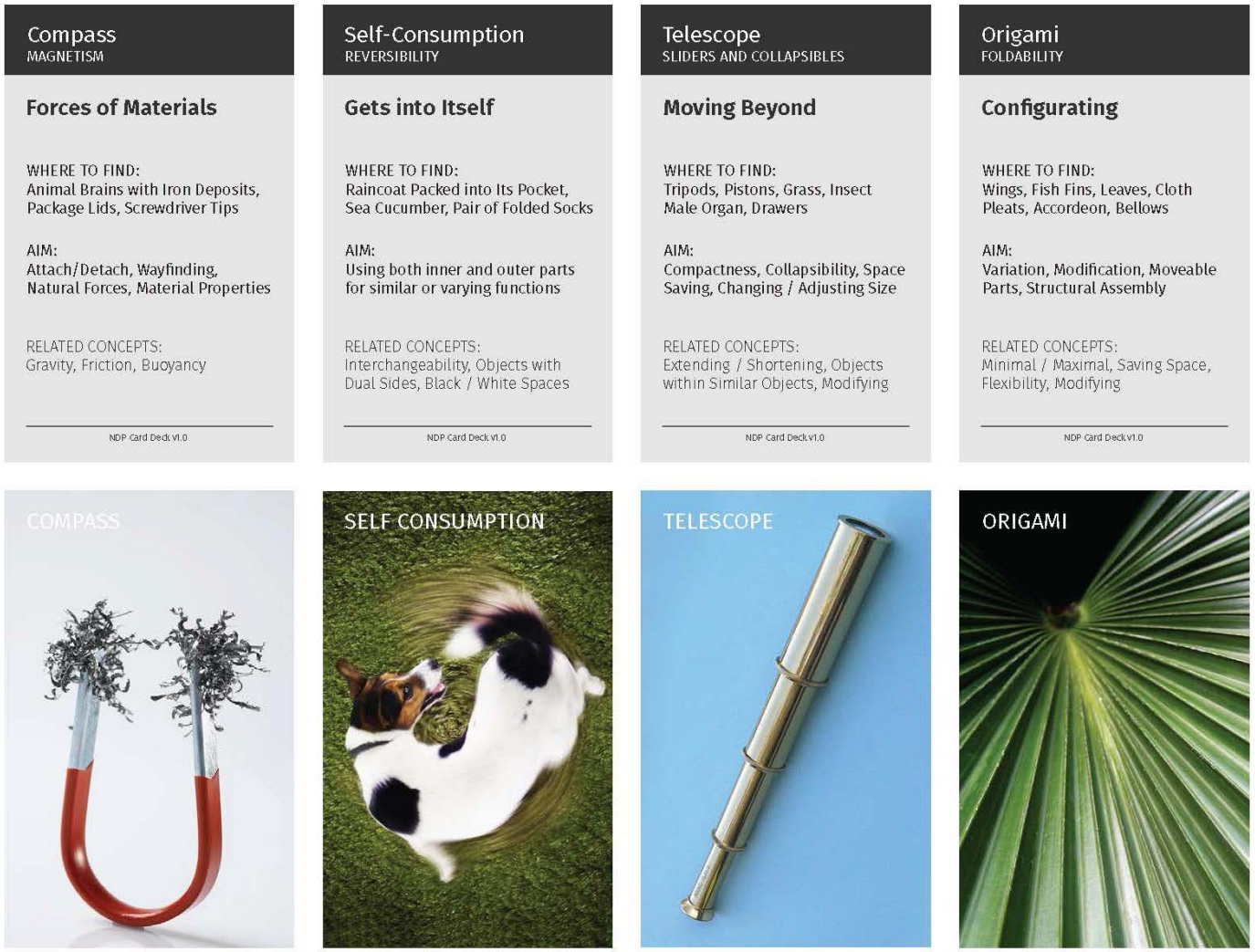


Figure C.1 – Nature Design Paradigms Card Deck (continued)

Figure C.1 – Nature Design Paradigms Card Deck (continued)

Figure C.1 – Nature Design Paradigms Card Deck (continued)

Figure C.1 – Nature Design Paradigms Card Deck (continued)

Figure C.1 – Nature Design Paradigms Card Deck (continued)

Figure C.1 – Nature Design Paradigms Card Deck (continued)

Spider Web
FILTERING

**From 2D to 3D**

WHERE TO FIND:
Colored Lens, Liver, Tennis Racket, Fish Net, Colander, Bodyguard

AIM:
Separation of Mediums/Materials, Portioning, Enclosure, Stopper

RELATED CONCEPTS:
Passages, Porousity, Fabric Mesh, Regular Patterns, Tensile Strength

NDP Card Deck v1.0


Fur
ORDER AND DISORDER

**Smaller and Bigger**

WHERE TO FIND:
Bed Pillow, Bird Feather, Shredded Paper, Spaghetti

AIM:
Modifying Size/Volume, Insulation, Compactness, Cushioning

RELATED CONCEPTS:
Size Through Order/Disorder, Neat Arrangement, Random Distribution

NDP Card Deck v1.0


Violin and Bow
INTERACTION OF PARTS

**Sensory Experience**

WHERE TO FIND:
Cricket's Chirp, Bow and Arrow, Matchstick Box,

AIM:
Functioning Using Both Parts, Complementary Objects, Rituals

RELATED CONCEPTS:
Binary Relationship, Combination of Parts, Epoxy

NDP Card Deck v1.0


Pencil Case
SETS AND KITS

**More Than Sum of Parts**

WHERE TO FIND:
First Aid Kits, Social Strata of Bees, Home Appliances with Accessories

AIM:
Variations on Single Task, Increase in Abilities, Different Size, Color etc

RELATED CONCEPTS:
Complementary Parts, Portability, Similar/Dissimilar Items, Combining

NDP Card Deck v1.0

## APPENDIX D

## WORKSHOP EXERCISE BRIEF

**METU Faculty of Architecture**
**Department of Industrial Design**

---

# Workshop: Designing Packaging with Nature Paradigms

**Date and Place:** 28 April 2014 Monday 10:30 – 17:30, ID Studio II (Room 32)

A workshop on packaging design will be held among METU ID students in line with a thesis study on implications of nature inspiration and design paradigms on packaging design process.

Aiming to increase designers' awareness of nature's principles, how these principles are applied in manmade environment, and how they can be transferred to product designs, workshop will introduce a toolkit to assist idea generation phase in designing packages. One-day program will include a presentation on the subject, group work on analysis of packaging concepts, introduction of the exercise method for concept generation and individual packaging design process.

All necessary visual materials will be available for the exercise, however you are required to bring;

- Examples of natural packaging, (can be collected from nature or bought from market)
- Examples of ingenious packaging designs,
- Drawing materials such as pencils and markers for sketching various concept ideas.

Facilitators:

Nur Yıldırım
Dr. Hakan Gürsu

# APPENDIX E

## NATURE DESIGN PARADIGMS PRESENTATION

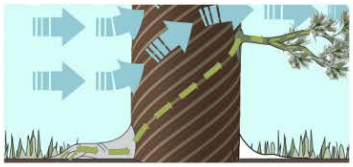

Figure E.1 – Nature Design Paradigms Presentation


Figure E.1 – Nature Design Paradigms Presentation (continued)

**Packaging Design**
Biomimicry Inspired Packaging Design

Banana Spots Inspired
Expiring Packaging

**Packaging Design**
Biomimicry Inspired Packaging Design

Vitalis Water Bottle
Inspired by spiral fibres on
whitebark tree trunk

**Packaging Design**
Biomimicry Inspired Packaging Design

Squeeze-open Bike Water Bottle
Inspired by Tricuspid Heart Valve

**What is a Paradigm?**

Characteristically, design paradigms are distinctive and comprehensive. Used as powerful tools for understanding the world, they create a framework for explaining the workings of natural and manmade objects.

**Employing Design Paradigms**

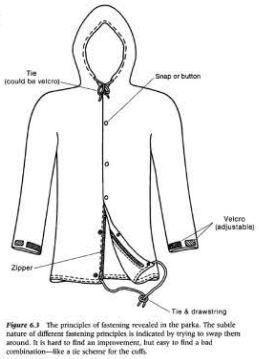



*Figure 6.3* The principles of fastening revealed in the parka. The subtle nature of different fastening principles is indicated by trying to swap them around. It is hard to find an improvement, but easy to find a bad combination—like a tie scheme for the cuffs.

**Nature Paradigms**
Paradigms Found in Packaging

Clamshell
Packages

Blister
Packaging

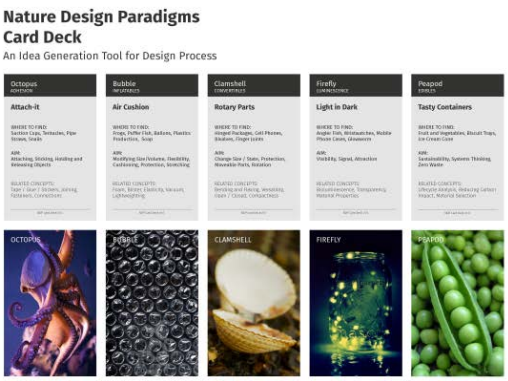
**Design Paradigms in Packaging**

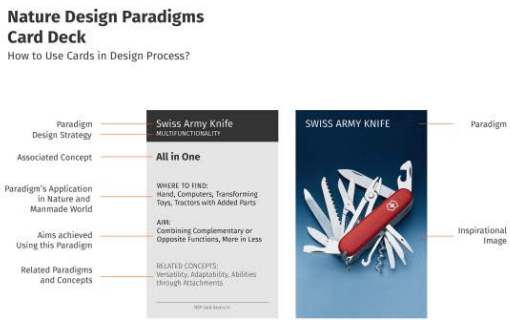
**Employing Design Paradigms**
Paradigms Inspired Packaging Design




Garbage Bags Packed
in a Garbage Bag

Figure E.1 – Nature Design Paradigms Presentation (continued)





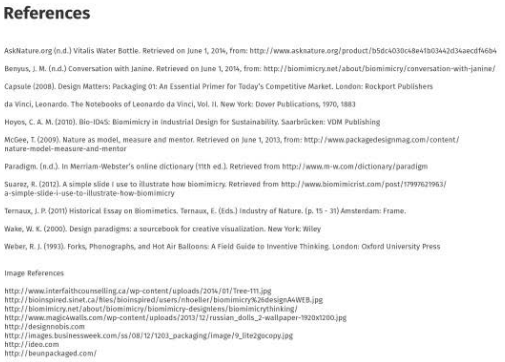



Figure E.1 – Nature Design Paradigms Presentation (continued)

## APPENDIX F

## EVALUATION SURVEY QUESTIONS

Q.1. Was the workshop process clear to you? Was the brief explanatory enough? Was the Card Deck's placement/utilisation in design process clear?

.....
.....
.....
.....
.....
.....
.....

Q.2. How would you evaluate the Presentation in workshop process? What points were influential/interesting? How did it influence the design process?

.....
.....
.....
.....
.....
.....
.....

Q.3. How do you think of the group conduct of the analysis phase followed by an individual conduct of the idea generation phase affected the ideation sessions?

.....
.....
.....
.....
.....
.....
.....

Q.4. What was your approach towards the design brief? Did you ideate on the concept as a whole, or did you develop specific parts of the packages?

.....
.....
.....
.....
.....

Q.5. Did you find the allocated time for each design sufficient? Were you comfortable in developing ideas within this time limit?

.....
.....
.....
.....
.....

Q.6. What do you think about the NDP Card Deck's design? Can you elaborate on;

- Images, keywords and their relation to paradigms and strategies,
- The way you utilised the cards in your process,
- The side and parts you used most?

Q.7. On the ways you made use of the cards;

- Did you use more than one paradigm in a single idea? Please exemplify.
- Did you make use of the cards independent from its context with different perspectives / features / qualities? Please exemplify.
- In which dimensions did you ideate (i.e. form, function, materials etc.)?

Q.8. Do you think the language of the cards (in English, not native) had effects (positive /negative) on your design process?

Q.9. How would you evaluate the structure of the cards? Were you comfortable in progressing through the cards? Would you prefer to have categories?

Q.10. How would you evaluate the Design Paradigms approach? Were the concept and introduced paradigms new or familiar? Would you consider using this design approach in the future?

Q.11. Did the exercise has an influence on your perception on nature, if so, in what way? Would you consider referring to nature in your future studies?

Q.12. How influential was the exercise for you in associating nature, paradigms and design? Were you aware of such a relationship and what would be your attitude towards the subject in future?

Q.13. How would you describe and evaluate the NDP Card Deck Exercise, could you elaborate on the process? What do you think of it as a design tool and how did it affect your design ideation process?

Q.14. What was the aim of this exercise in your opinion? Do you think you have achieved this aim? Could you explain?

.....
.....
.....
.....
.....
.....
.....

Q.15. How would you evaluate your performance and the design ideas you developed through the exercise? Would you consider improving these concepts further for use?

.....
.....
.....
.....
.....
.....
.....
.....

Q.16. Were there any difficulties you faced in the workshop process? Could you make suggestions on improving this exercise?

.....
.....
.....
.....
.....
.....
.....

Q.17. Comments and further thoughts.

.....
.....
.....
.....
.....
.....
.....

# APPENDIX G

## CONSENT FORM FOR PARTICIPANTS

**CONSENT FORM**

Research Project Title: The implications of nature inspired design paradigms on idea generation process
Investigator: Nur Yıldırım, M.Sc. Student, Middle East Technical University

I am a M.Sc. student in the Department of Industrial Design and I am carrying out a study which aims to investigate the implications of nature paradigms for design process, and to find out how nature inspired design would be integrated into the design idea generation process. My research involves the analysis of the outcomes of the student projects (i.e. products and product ideas generated during the workshop carried out) by considering card deck use and semi-structured interviews with industrial design students to provide insights on design process . The research results will provide a basis for the development of papers for journal publications and for the completion of my Master Thesis.

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

I wish to interview you because of your attendance and performance in the workshop. Your participation would involve answering questions in a survey, which is expected to take approximately 20-25 minutes. The interviews will be audio taped. Your participation is voluntary and you may withdraw from the study at any time, in which case your responses would not be used. As the survey questions are related to your work performed during the workshop, I may request to observe visual representations of your ideas (i.e. sketches, drawings etc.). Your participation is voluntary and you may withdraw from the study at any time, in which case any visual representations would not be used.

For the survey and the observation, two options are provided below for the confidentiality agreement;

For the survey:
_____ My name may be used in the Master Thesis and journal publications in connection with the information I provide.
_____ I wish to remain anonymous. My name will not be used and the information that I give will not be connected to my identity in any way.

For the observation:
_____ My name may be used in the Master Thesis and journal publications in connection with the visual representations (i.e. sketches, drawings) that I provide may be used in the Master Thesis and journal publications.
_____ Visual representations (i.e. sketches, photographs) will be kept confidential; they will not be published in any way.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time. If you have further questions concerning matters related to this research, please contact:

Nur Yıldırım, M.Sc. Student
Industrial Design Dept., Faculty of Architecture
Midle East Technical University
Phone: 0 312 210 1179
E-mail: nur.yildirim@metu.edu.tr

Dr. Hakan Gürsu, Supervisor
Industrial Design Dept., Faculty of Architecture
Midle East Technical University
Phone: 0 312 210 2247
E-mail: gursu@metu.edu.tr

Participant's Signature
Date

Investigator's Signature
Date

A copy of this consent form has been given to you to keep for your records and reference