ALARA TİGREL

A COMPARATIVE STUDY ON THE ROLE OF ANALOGICAL REASONING IN SUSTAINABLE PROBLEM SOLVING

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A COMPARATIVE STUDY ON THE ROLE OF ANALOGICAL REASONING IN SUSTAINABLE PROBLEM SOLVING

A Master's Thesis

by

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A COMPARATIVE STUDY ON THE ROLE OF ANALOGICAL REASONING
IN SUSTAINABLE PROBLEM SOLVING

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June 2017

I certify that I have read this thesis and have found that is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

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ABSTRACT

A COMPARATIVE STUDY ON THE ROLE OF ANALOGICAL REASONING IN SUSTAINABLE PROBLEM SOLVING

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June 2017

Analogy is the name given to the process of receiving knowledge from a learned and an experienced concept and using the acquired knowledge in a new concept. Analogical reasoning is a concept, which is commonly used in design education and problem solving. Analogical reasoning can be used as an help in the process of problem solving. Sustainability is a concept, which can be interpreted differently according to the field of use. The concept of sustainability should be an essential part of design education and combined with its entire curriculum. In the scope of this knowledge, this thesis aims to find out whether the use of analogical reasoning in the sustainable problem solving process improves the overall solution and simplifies the process or not.

Keywords: Analogical Reasoning, Analogy, Creativity, Success, Sustainable Problem Solving

ÖZET

ANALOJİK AKIL YÜRÜTMENİN SÜRDÜRÜLEBİLİR PROBLEM ÇÖZÜMÜNDEKİ ROLÜ ÜZERİNE KARŞILAŞTIRMALI BİR İNCELEME

Tigrel, Alara

İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı

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Analoji, daha önce öğrenilen bir bilgiyi ve elde edilen deneyimi yeni bir konseptte kullanma sürecine verilen isimdir. Analojik akıl yürütme tasarım eğitiminde, öğrenme ve problem çözme sürecinde yaygın olarak kullanılan bir konsepttir. Tasarım eğitiminde analojik akıl yürütme, öğrencilerin problem çözme sürecini kolaylaştırma amacıyla bir yardım aracı olarak kullanılabilir. Sürdürülebilirlik kavramı, günümüzde tasarım eğitiminin vazgeçilmez bir parçası olma yönünde ilerlemektedir ve bu kavram tasarım eğitiminin tüm müfredatına entegre edilmelidir. Bu tezin amacı sürdürülebilir problem çözme sürecinde analojik akıl yürütmenin bir araç olarak kullanılması, genel çözümün kalitesini artırıp artırmadığı ve problem çözme sürecini kolaylaştırıp kolaylaştırmadığını bulmaktır.

Anahtar Kelimeler: Analojik Akıl Yürütme, Analoji, Başarı, Sürdürülebilir Problem Çözümü, Yaratıcılık

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CHAPTER I

INTRODUCTION

Analogy is the name given to the process of transferring knowledge and information from previously experienced problems and using this knowledge in the solution of a new problem (Gentner, 1998; Gentner & Smith, 2012; Gick & Holyoak, 1980; Holyoak & Thagard, 1989). Analogical reasoning is a cognitive process, which has an impact on the student's problem solving and design decisions (Gick & Holyoak, 1980; Ozkan & Dogan, 2013). In order to transfer knowledge and information from a particular problem to an unsolved problem, a common relational system must be formulated between the prior concept (the source) and the new concept (the target) (Gentner & Smith, 2012). In recent studies the use of analogical reasoning in problem solving was found to be essential for both quality of the solution and also understanding the problem (Gick & Holyoak, 1980; Gick & Holyoak, 1983; Holyoak, 1985; Melis & Veloso, 1998; Visser, 1996). In recent studies the use of analogical reasoning in various fields has been a popular topic (Fu, Chan, Cagan, Kotovsky, Schunn & Wood, 2013; Gick & Holyoak, 1980; Melis & Veloso, 1998).

Sustainability is a concept, which can vary according to the field of use. It is an undeniable fact that sustainability is an uprising issue in design education (Bala, 2010). In recent studies it is suggested that sustainability should be combined with the entire curriculum of design education and that design education should have the approach of a sustainable worldview (Bala, 2010; Gürel, 2010; Shephard, 2008). Besides the curriculum change in design education, students should be encouraged to take courses related to environmental studies (Fisher & McAdams, 2015; Gürel, 2010; Smith-Sebasto, 1995). Studies show that students, who take courses in environmental studies, develop a more responsible behavior towards the environment (Fisher & McAdams, 2015; Shephard, 2008). It is a fact that with this expanding sustainability worldview, students' awareness on and curiosity about sustainability is also increasing (Stark & Park, 2016). In this respect, in order to ease the process of sustainability learning and increase its awareness, it is considered that analogical reasoning can be used. In design education analogical reasoning is used as help for the problem solving, learning and development process. In this respect, it is considered that the use of analogical reasoning in sustainable design education can be helpful for students' sustainable problem solving process.

1.1 Problem Definition and Thesis Objectives

In the scope of the literature review, it can be said that analogical reasoning is a widely used concept in education as an improvement tool. It can be used in different roles in education such as facilitation during the learning stage and as an improvement during the problem solving stage. Sustainability is an uprising subject in design education. It is a subject, which should be taught thoroughly in design education. Thus, the main objective of this thesis is to analyze the role of analogical reasoning in sustainable problem solving. The study aims to find in which ways the use of analogical reasoning is beneficial to sustainable problem solving.

1.2 Structure of the Thesis

This thesis contains five chapters. In Chapter 1, a brief introduction is followed by the definition of the problem. In Chapter 2, first, definition of analogy and analogical reasoning are given. Then the role of analogical reasoning in design is investigated. Within the scope of this part, the use of visual analogy, its impact in design and the key constituents of analogical reasoning, which are the source and the target, are explored. In Chapter 3, sustainability is defined. Its integration into the entire curriculum of interior design education is elaborated. In Chapter 4, first, the aim of the study is given. Afterwards research question of the study and hypotheses are presented. Then, the method of the study, participants, tasks and procedure are explained respectively.

In Chapter 5 the results are given and analyzed in three parts; descriptive analysis results of problem setting 1, descriptive analysis results of problem setting 2 and comparison analysis results of problem setting 1 and problem setting 2, respectively. In the first part the results of all tasks in problem setting 1 are presented. In the second part, the results of all tasks in problem setting 2 are presented, and in the third part the results are given in four categories, namely success findings, mental effort findings, stated design criteria findings, and creativity findings. In the third part, a comparison is also made between the results of problem setting 1 and problem setting 2. In the fourth and the final part of Chapter 5, an overall discussion is made. In Chapter 6, general features of the thesis are given as summary. Then the importance and role of this thesis for the literature are given and concluding remarks are made.

CHAPTER II

ANALOGICAL REASONING

2.1 Definition of Analogy

Analogy is a process of retrieving and transferring previously gained knowledge and information from prior concepts (the source) to form the base of a new concept (the target) with an aim to find a solution to a specific problem (Gentner, 1998; Holyoak & Thagard, 1989). In analogy, the fundamental structure is retrieved from the source example in order to understand the target example and find a solution (Hey, Linsey, Agogino & Wood, 2008). In order to use analogy in reasoning, a common relation system should be reached between the source and the target (Gentner & Smith, 2012). This common relation system, which is retrieved and formed from the source, is used in the target as help. Common relation system can include concrete similarities between the source and the target, but it is not necessary for analogy (Gentner & Smith 2012). In order to retrieve an analogy, just a relational connection between the source and the target is sufficient (Gentner & Smith, 2012; Herstatt & Kalogerakis, 2005).

Analogical reasoning is a critical and important cognitive process, which involves using relational and physical similarity between two situations, that may affect students' learning stage, problem solutions and design decisions (Chai, Cen, Ruan, Yang & Li, 2015; Gentner & Smith, 2012; Gick & Holyoak, 1980; Ozkan & Dogan, 2013). In analogical reasoning, designers use the information from prior concepts to form the base of a new concept and it is essential to give the reasons about the similarity. Human cognition can perceive the relational and physical similarity between two elements and use this information while forming the new element (Gentner & Smith, 2012). In other words, analogical reasoning is basically used as an assistance in the solution of the target problem (unsolved problem) with the help of the previous problems, assumed as the source problems (previously solved problem) (Gick & Holyoak, 1980; Herstatt & Kalogerakis, 2005). In most studies, analogical reasoning has been found critical for problem solution, scientific discovery, decision-making and creative thinking (Chai et. al., 2015; Gick & Holyoak, 1980; Holyoak, 1985; Melis & Veloso, 1998).

2.2 Analogical Reasoning in Design

Analogical reasoning has been widely used in many fields, such as design, economics, and psychology (Fu et. al., 2013; Gick & Holyoak, 1980; Melis & Veloso, 1998). Use of analogical reasoning in design is common. Most architects and interior architects get inspiration from various sources from daily life and previous projects (Cai, Do & Zimring, 2010).

In design education, reviewing architectural case studies could be a source of inspiration. Furthermore keeping up to date with the recent developments would be beneficial for the upcoming projects (Gentner & Toupin 1986; Ozkan & Dogan, 2013). In every stage of design education, from early conceptual phase to detailing, analogical reasoning can be used (Gentner & Toupin, 1986). It is mostly used in the early stages of a design project such as the idea and concept generation stage (Hey et. al., 2008). In the idea generation stage, professionals in design major can get help from their background experiences and students can get help from analogy (Gonçalves, 2013; Keller, Sleeswijkvisser, Vanderlugt & Stappers, 2009). The use of analogical reasoning in design education is not only for students but also for design educators and professionals working in practice (Kalogerakis, Lüthje & Herstatt, 2010). For design students, it helps to improve their creativity and simplifies the learning stage (Cubukcu & Dundar, 2007; Kalogerakis et. al., 2010). For educators and design professionals in the design field, it helps to keep up to date with the recent developments in the design field and improve their education style (Herstatt & Kalogerakis, 2005; Kalogerakis et. al., 2010; Ozkan & Dogan, 2013).

2.2.1 Use of Visual Analogy in Design

Analogical reasoning can be used in various methods like, words, sentence clues, and pictures (Malaga, 2000; Smith, Ward & Schumacher, 1993). Previous studies show that visual thinking and using visual analogy are critical for design problem solving because visual analogies help designers more than other forms (Bilda, Gero & Purcell, 2006; Chai et. al., 2015). In design education students are encouraged to think and express their thoughts visually and visual thinking is assisted by visual display such as pictures, sketches and graphics (Goldschmidt, 1995). Another study by Bonnardel (2000) suggests that mentioning the name of the object and letting the participants picture the object is more beneficial and invoke more analogies rather than directly showing pictures to the participants (Bonnardel, 2000; Ozkan & Dogan, 2013). In order to get students' attention or direct them to picture the final project, educators encourage visual analogy.

In previous studies, it has been found that use of visual analogy during a design problem has a strategic importance among students (Cai et. al., 2010; Casakin & Goldschmidt, 1999). Alongside the design literature, there is empirical evidence suggesting that use of visual analogy during a design problem increases the quality of the final design solution (Casakin, 2004; Casakin & Goldschmidt, 1999; Cubukcu & Dundar, 2007; Verstijnen, Wagemans, Heylighen & Neuckermans, 1999). Visual analogy alongside the quality of the design problem, also affects the originality (Cai et. al., 2010; Goldschmidt &

Smolkov, 2006). The studies show that in order to have a successful design solution, use of visual analogy during the design stage is critical (Casakin, 2004; Casakin & Goldschmidt, 1999). However, while designing there is also a risk of fixation in using visual analogies. Using visual examples like pictures, photographs and sketches may lead to design and cognitive fixation among designers and also students (Linsey, Wood & Markman, 2008; Ozkan & Dogan, 2013). While using visual analogy design fixation can occur unconsciously and hence it is difficult to reduce (Brown & Murphy, 1989; Cheng, Mugge & Schoormans, 2014; Linsey, Tseng, Fu, Cagan, Wood & Schunn, 2010).

Moreover the selection of visual examples are critical, because it is found that showing familiar visual examples to the participants tend to lead to design fixation, while showing unfamiliar visual examples tend to have no such effect (Bonnardel, 2000; Chai et. al., 2015). Studies also show that using abstract examples lead participants to be more creative and original, improve the quality of the design and results in less design and cognitive fixation (Cardoso &Badke-Schaub, 2011; Casakin & Goldschmidt, 1999; Chai et. al., 2015; Linsey et. al., 2008). In order to transfer prior information and knowledge, the level of abstraction in the example becomes important and can affect analogical problem solving. Alongside the abstraction, forms of the visual sources also have an impact on designers' response. Use of different kinds of visual sources like pictures, sketches (conceptual examples) and 3D prototypes (physical examples) affects the designers' analogical strategy (Christensen & Schunn, 2007). Designers' who are exposed to physical examples usually go through within-domain analogies, while designers' who are exposed to conceptual examples go through between-domain analogies (Chai et. al., 2015; Christensen & Schunn, 2007).

2.2.2 Distance Between Source and Target

Analogical reasoning involves transferring previously gained knowledge and information from an already solved problem (the source) to a new problem, which should be solved (the target) (Gentner, 1983; Novick, 1988; Visser, 1996). In order to achieve a solution, a potential similarity should be identified and retrieved from the source. These potential similarities help participants to understand the situation and identify them as a familiar situation (Casakin, 2004). According to different studies, there are two categories of analogy, namely surface and structural (deep) analogy (Gentner, 1983; Rips, 1989; Vosniadou, 1989). Surface analogies are attributional and it is easy to access and identify these analogies (Casakin, 2004; Chai et. al., 2015; Dejong, 1989; Gentner, 1983). Participants can easily retrieve similarities from surface analogies. Studies by Gentner (1983) and Keane (1988) show that as easy as it is to retrieve similarities, it is not easy to understand the structural similarities from surface analogies and transfer them from the source to the target. On the other hand, structural analogies are usually abstract and they involve relational similarities. Therefore, it is more difficult to identify the structural analogies (Ozkan & Dogan, 2013; Vosniadou & Ortony, 1989). A deep understanding of the relation and the similarity between the source and the target is needed. Structural analogies have a more positive impact on the quality of the solution (Casakin, 2004).

Analogies are mostly formed through two different examples, which are between-domain and within-domain (Casakin, 2004; Johnson & Laird, 1989). Each example requires a different knowledge and perspective but they have a common relation of sharing either surface or structural similarity between the source and the target. When the source and the target problem belong to the same or very similar examples, this forms the within-domain analogies (Casakin, 2004). On the other hand, when the source and the target problem belong to different and distant examples, this forms the between-domain analogies. Between-domain analogies are more difficult to retrieve, because of the structural similarities between the source and the target (Dahl & Moreau, 2002; Reeves & Weisberg, 1994). However, if between-domain analogies are achieved, it increases the quality and the success of the target problem solution (Vosniadou, 1989). On the other hand within-domain analogies are easy to retrieve because of the surface similarities (Casakin, 2004; Dejong, 1989). Basically the difficulty of accessing and transferring similarities depends on the distance between the source and the target (Casakin, 2004; Johnson & Laird, 1989).

The distance between the source and the target is conceptual and it is used to form analogies. Previous studies contain many definitions and terminology about the distance, such as within-domain versus between-domain, local versus distant and near versus distant (Vosniadou & Ortony, 1989). All of these terms refer to the same conceptual distance between the source and the target (Christensen & Schunn, 2007; Ozkan & Dogan, 2013). Students who have different expertise levels can prefer different source examples when it comes to solving the problem. In order to increase the variability of the source examples a third category between near and distant source examples are proposed by different studies, which is the medium source example category (Chai et. al., 2015; Kalogerakis et. al., 2010; Ozkan & Dogan, 2013). Generally near source categories involve similar product examples, medium source categories involve different product examples and distant source categories involve non-product examples, which can be animal, plant and natural examples (Chai et. al., 2015; Fu et. al., 2013; Kalogerakis et. al., 2010; Ozkan & Dogan, 2013). In this study the distance is categorized into three source example categories: near, medium and distant, similar to the study by Kalogerakis et al. (2010), and Chai et al. (2015).

2.3 The Relationship Between Expertise and Visual Analogy

Designers with different expertise levels can easily use analogical reasoning. Previous studies show that designers with higher expertise level prefer medium source examples while using visual analogy for solving a design problem (Kalogerakis et. al., 2010). There is a difficulty of access to the source examples and retrieving visual analogies from the source while solving a design problem (Gick & Holyoak, 1980; Needham & Begg, 1991). Using visual analogy requires a deep knowledge of the subject, problem and field of the problem. Knowledge, which designers gain through design education and projects, can assist the problem solving stage and it is associated with the use of visual analogy (Casakin, 2004; Dominowsky, 1995).

Past researches showed that the level of expertise was found to have a positive relationship with the use of analogy (Casakin, 2004; Daehler & Chen, 1993; Vosniadou, 1989). The more the expertise level is increased, the more it becomes easier to retrieve visual analogies increasing the quality of the solution (Casakin, 2004). Experience in design area allows designers to easily retrieve abstract, physical and structural examples from source examples and use these examples in the target problem (Casakin, 2004; Gick & Holyoak, 1980). Experts in design area are more concentrated while solving design problems and are more likely to retrieve applicable aspects from the source examples (Casakin, 2004).

This knowledge helps designers to represent their ideas in a more accurate way. Therefore the level of expertise is critical for using visual analogy during a design problem in order to achieve accurate and reliable solutions.

2.4 The Relationship Between Creativity and Visual Analogy

Visual analogies are widely used to enhance creativity among designers (Casakin & Goldschmidt, 1999; Casakin & Goldschmidt, 2000; Cubukcu & Cetintahra, 2010). Visual analogies can both have a positive or negative impact on designers' creativity (Cubukcu & Cetintahra, 2010; Gick & Holyoak, 1980; Goldschmidt, 2001; Malaga, 2000). In order to improve students' creativity, analogical reasoning should be used efficiently with good examples (Casakin & Goldschmidt, 1999; Casakin & Goldschmidt, 2000). Students' creativity can be affected negatively if analogical reasoning is not used properly with appropriate visual examples (Cubukcu & Cetintahra, 2010). In previous studies there are two different approaches to the relationship between visual analogies and creativity. Ward (1998) suggested that according to the design problem there could be a positive or negative relationship between creativity and the problem itself (Ward, 1998). Design problems, which are previously solved in a sufficient way, could lead an improvement in creativity of students (Casakin & Goldschmidt, 1999; Cubukcu & Cetintahra, 2010; Cubukcu & Dundar, 2007).

Other studies suggest that, use of visual analogies can impact creativity in either a positive or negative way (Casakin & Goldschmidt, 1999; Casakin & Goldschmidt, 2000; Malaga, 2000; Schwert, 2007). Use of good visual analogies in a design problem improves the creativity of the student, by providing them various visual examples. The correlation between creativity and the quality of the design is positive, related with the visual analogies, so when creativity of the student improves, the quality of the design solution improves too (Chai et. al., 2015; Cubukcu & Dundar, 2007). Also there is a positive relationship between creativity and success of the student.

CHAPTER III

SUSTAINABILITY

3.1 Definition of Sustainability

Sustainability is a concept that can vary according to the major under consideration. Every major has its' own kind of definition and interpretation of sustainability. The most common definition of sustainability in environmental studies is the one from the report of the United Nations' Brundtland Commission on Environment and Development. According to this report, sustainability can be described as making development in a beneficial way for both the present and the future population without risking the future populations' ability of meeting their needs (United Nations' Brundtland Commission on Environment and Development, 1987). Achieving sustainability in environmental studies, also, requires making developments in order to provide people a better life style. This definition still remains the most acceptable and common definition of sustainability in environmental studies (Stark & Park, 2016).

The concept of sustainability has its own limitations, brought about by the current state of social life and technology. Even though the concept of sustainability has limitations, it can be evolved and improved according to the current social, economic environment and also technological developments. There is a tendency among people to relate the term sustainability to the basic environmental issues. In recent years thanks to developing concepts of environmental preservation and energy efficiency, understanding of sustainability has changed (Fisher & McAdams, 2015).

3.2 Sustainability in Design Education

In recent years the concept of sustainability turned into a topic that every designer, architect, interior architect should take into consideration. Sustainability is also a widely used concept among design education. It is a fact that the importance and awareness of sustainability has increased in recent years as a result of the sustainability movement, mentioned in the United Nations' Brundtland Commission on Environment and Development (Gosselin, Pamell, Smith-Sebasto, & Vincent, 2013; United Nations' Brundtland Commission on Environment and Development, 1987). According to The Association of Collegiate Schools of Architecture (ACSA), The American Institute of Architects (AIA), The National Council of Architectural Registration Boards (NCARB) and many other corporations, sustainability should no longer be just a concept that is taught in design education by choice (Bala, 2010). It is claimed that sustainability education should be an essential part of any architectural education. It should be addressed in all courses in the curriculum of architectural education and not just in one course (Gosselin et. al., 2013). Previous studies also showed that architectural education should be designed with a sustainable worldview approach (Bala, 2010).

In architectural education, it is essential to introduce the students to sustainability in the early stages of design education (Bala, 2010; Gürel, 2010). This is because the design decisions, taken during the early stages, have an important role in shaping the sustainable architectural awareness for the future architects and interior architects (Bala, 2010; Shepard, 2008). According to studies by Rowe (2002) and Sauve (1996) sustainability should be a course that is given in various fields such as; architecture, interior architecture, and engineering, in order to increase students' environmental awareness (Rowe, 2002; Sauve, 1996). Previous studies show that sustainability can be fully integrated into the design education, enabling students to have an introduction to sustainability in the early stages of their education (Gürel, 2010; Shepard, 2008). Moreover, it is beneficial for architecture and interior architecture students to take courses in environmental studies in order to develop a more environment conscious behavior (Fisher & McAdams, 2005; Smith-Sebasto, 1995). In order to increase students' awareness of sustainability, it is important that design education acquires full grasp of sustainable development beforehand (Gürel, 2010; Papanek, 1995).

3.3 Assessment Criteria of Sustainability

After the UN’s declaration, the period 2005-2014 became the decade of education for sustainability, and sustainability gained importance among educators, universities and students (Connell & Kozar, 2012). Sustainability is not just a concept that can be taught by giving information about its definition, materials and indoor environmental quality (Fisher & McAdams, 2005; Zuo, Leonard, & Malonebeach, 2010). Teaching sustainability should not only involve the basic terms and environmental issues. Also the terms and concepts related to sustainability such as energy efficiency, water efficiency and also indoor air quality should be given to students (Fisher & McAdams, 2005; Kang, Kang & Barnes, 2009). In the report of the United Nations’ Brundtland Commission on Environment and Development sustainability and concepts related with sustainability are addressed (United Nations’ Brundtland Commission on Environment and Development, 1987). After the Brundland Report, sustainability became a concept, which is addressed and reviewed in many conferences (Winchip, 2007). There are many organizations, programs and certification programs related with sustainability in many countries (Winchip, 2007). Students can get information about sustainability from these organizations and certification programs such as; United Nations’ Brundtland Commission on Environment and Development, United States Green Building Council, LEED (Leadership in Energy and Environmental Design) in United States (Winchip, 2007).

The LEED certification program is based on five categories, which are 1- Sustainable Sites, 2- Water Efficiency, 3- Energy and Atmosphere, 4- Materials and Resources and 5- Indoor Environmental Quality (Winchip, 2007). Also professionals and students who are interested in sustainability can get education and be LEED green associates. Being a LEED green associate means that a person who has an up-to-date document about sustainability and green building regulations (Cottrell, 2010; Knox, 2014). In order to educate students with these concepts and integrate sustainability into design, also sustainability assessment tools, regulations about sustainability and programs should be taken into consideration in design education (Fisher & McAdams, 2005; Winchip, 2007).

CHAPTER IV

METHODOLOGY

4.1 Aim of the Study

A review of existing literature shows that analogical reasoning is used in design education as an improvement tool. It is also used to facilitate the process of design in design education. Sustainability and sustainable problem solving on the other hand is an uprising subject in design education. Thus, the aim of this study is to explore the role of analogical reasoning in sustainable problem solving by comparing the differences among 3rd year interior architecture students, who are using visual analogy and traditional design methods to solve sustainable design problems.

4.1.1 Research Question

In order to reach the aim of the study only one research question was formulated for this thesis. The research question of this thesis is as follows:

In which ways analogical reasoning enhance sustainable problem solving in interior design education?

4.1.2 Hypotheses

In response to this research question, four hypotheses are formulated. The hypotheses are as follows:

H1: There is statistically significant success difference (in problem solving) between student groups based on the use of analogical reasoning.

H2: There is statistically significant mental effort difference (in problem solving) between student groups based on the use of analogical reasoning.

H3: There is statistically significant stated design criteria difference (in problem solving) between student groups based on the use of analogical reasoning.

H4: There is statistically significant creativity difference (in problem solving) between student groups based on the use of analogical reasoning.

4.2 Method of the Study

4.2.1 The Course Structure

In order to examine the role of using analogical reasoning in sustainable problem solving, the study is conducted in the course titled ‘IAED 342 Sustainable Design for Interiors’. The course is given to undergraduate Interior Architecture and Environmental Design students in the third year of their education.

4.2.2 Participants

In order to understand the role of using analogical reasoning in sustainable problem solving 3rd year undergraduate students from the Department of Interior Architecture and Environmental Design at Bilkent University were chosen from the 2016-2017 Spring Semester. The reasons behind the selection of 3rd year students are as follows:

(1) In the 3rd year of Interior Architecture and Environmental Design education in Bilkent University students have an obligation to take IAED 342 Sustainable Design for Interiors course, which introduces them to sustainability and allows them to apply this knowledge to design projects.

(2) Compared to 1st and 2nd year students, 3rd year students have more knowledge and experience in the design field; therefore the use of analogical reasoning is easier.

Sample group of this research was divided into two problem setting groups, each of which had the same number of students to solve the same problem, but differed in terms of the way they were asked to solve the problem (Figure 1). One group was the first section of the course, which was composed of 64 students using analogical reasoning method for problem solving, and the other group was the second section of the course with the same number of students using traditional methods for problem solving rather than analogy. The aim of this division was to compare the two sample groups in terms of the role of analogy during the sustainable design problem solving process. A total of 128 undergraduate students from 3rd year participated to the survey. In the first group 55 of them were female while 9 of them were male students, in the second group 53 of them were female while 11 of them were male students.

4.2.3 Procedure

In this thesis there are two problem settings (Figure 1). The first problem setting is composed of four tasks, whereas the second problem setting is composed of two tasks. Tasks are conducted for both Problem Setting 1 and Problem Setting 2 as a homework assignment. Participants were informed about the study and the tasks in two different days because of the dates of the IAED 342 course (See Section 4.2.1). A survey, which is composed of four tasks were given to participants in Problem Setting 1 as handouts on the 27th of February (See Appendix A). The handouts of the tasks were given to participants in Problem Setting 2 on the 1st of March (See Appendix A and B).

At the outset of both Problem Setting 1 and Problem Setting 2, all of the participants were told that their goal was to design a sustainable workstation unit, defined as an area that has the equipment needed for one person to do a particular job. The equipment in this problem includes a desk, a shelf and a lighting element (See Appendix A and B). In both Problem Setting 1 and Problem Setting 2 students were given brief information about the requirements and informed that the study will be collected after 10 days. For Problem Setting 1 the study was due to 8^{th} of March and for Problem Setting 2 it was due to 10^{th} of March. In both settings, the students were asked to fill out a mental effort survey, attached to the tasks, at the end of the problem, in which the students assessed themselves for the mental effort they put in during the problem solving process (See Appendix C).

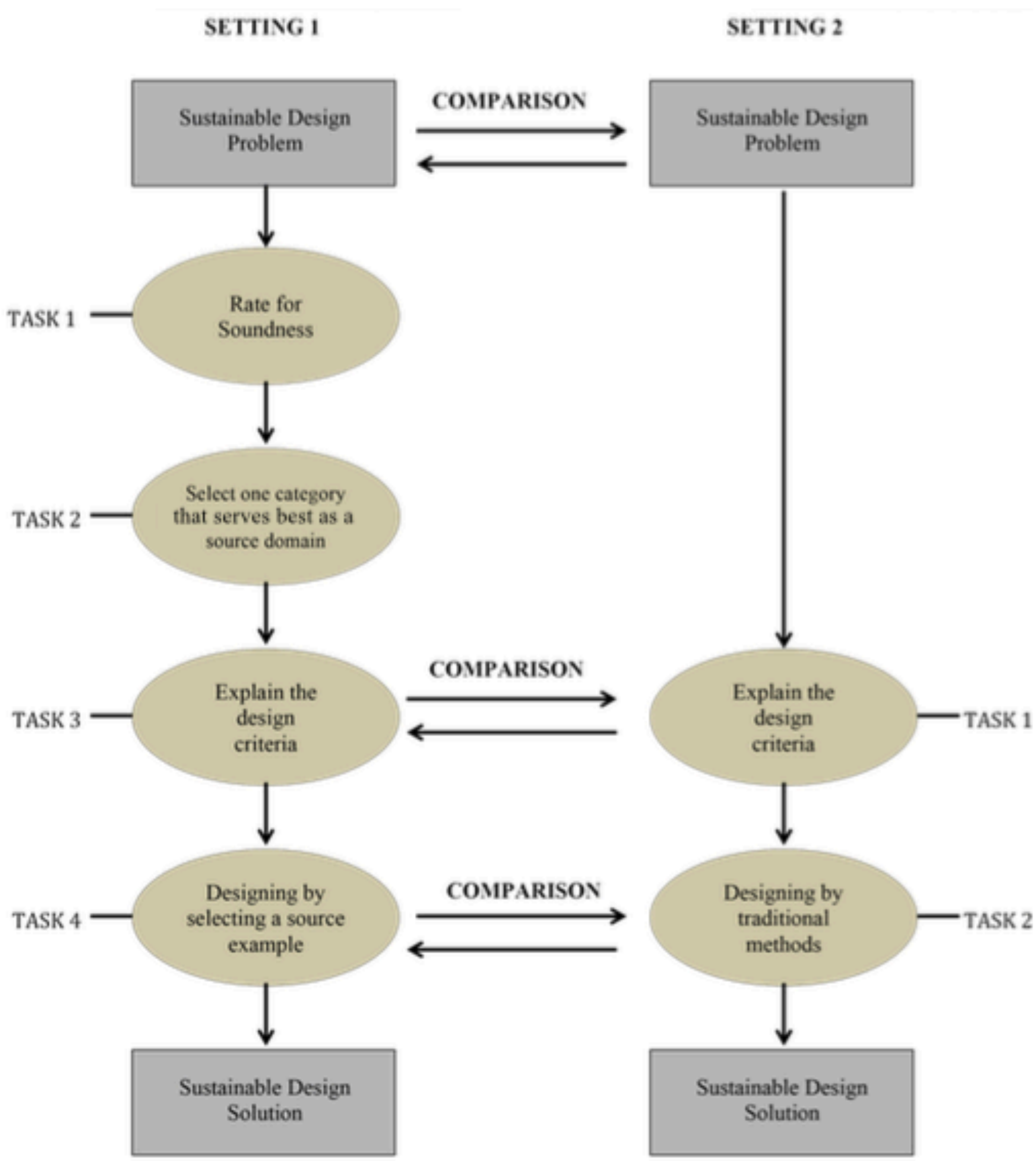

Figure 1. Theoretical framework of the research, drawn by the author, 2017.

4.2.2.1 Tasks in Problem Setting 1

There are four tasks in the first problem setting. For the first task (Task 1) (See Appendix A), participants were asked to rate 30 examples for the appropriateness of the example in the context of the given problem, designing a workstation unit, by using a five point Likert scale (1- Poor, 2- Fair, 3- Average, 4- Good, and 5- Excellent). At the beginning of this task the participants were required to assess the usability of each example as a solution for designing a workstation unit. The examples were selected from near, medium and distant source categories with reference to the study by Ozkan & Dogan (2012) and Chai et al. (2015).

In the second task (Task 2) (See Appendix A), the participants were asked to select only one source example among the thirty examples of the three categories (Figure 2). The participants were asked to select an example, which would best serve as a solution for designing a workstation unit. The participants were specifically informed to select only one example, because the selected example will be used as an analogy in their final design of the sustainable workstation unit (Task 4).

In the third task (Task 3), the participants were asked to choose a design criterion from an 8-category items related with the example that they chose in Task 2 (See Appendix A).

The eight categories were *aesthetics, experience, form, function, originality, physical property, structure and usability* (Table 1). The 8-category items were modified from the one used in the study by Ozkan & Dogan (2012). The participants were specifically informed to select only one design criterion, because the selected criterion will be related with the selected example from second task and used as a concept in their final design of the sustainable workstation unit (Task 4).

Table 1. 8-category items

Categories	Definition
Aesthetics	Sense of form, art, or visual pleasing sensation that source example invokes.
Experience	A similar project has been done or observed by the participant.
Form	Shape, and other external visual appearance of the source example.
Function	The way the source example will benefit or serve its users.
Originality	Novelty and difference.
Physical Property	Material, texture, or color of the source.
Structure	The relationship among the elements of source example.
Usability	Availability for all people regardless age, ability and size.

In the fourth task (Task 4), the participants were told to design a sustainable workstation unit using analogy to the selected source example (See Appendix A). The participants were asked to illustrate their design solutions with plan, elevation and perspectives on an A3 page. Three independent experts (a LEED green associate architect, a LEED green associate interior architect, and a industrial designer) evaluated all of the designs produced in both problem settings (See Section 4.3.1).

4.2.2.2 Tasks in Problem Setting 2

There are two tasks in the second problem setting. In the first task (Task 1), same as the third task (Task 3) from Problem Setting 1, the participants were asked to select a design criterion, from the same 8-category items, which best suits to their sustainable workstation unit design (See Appendix B). The eight categories were *aesthetics, experience, form, function, originality, physical property, structure and usability* (Table 1, Ozkan & Dogan, 2012). The participants were specifically informed to select only one design criterion, because the selected criterion will be used as a concept in their final design of the sustainable workstation unit (Task 2).

In the second task (Task 2), the participants were told to design a sustainable workstation unit based on their sustainability knowledge (See Appendix B). As in Problem Setting 1, the participants were asked to illustrate their design solutions with plan, elevation and perspectives on an A3 page. The same three independent experts (a LEED green associate architect, a LEED green associate interior architect, and a LEED green associate industrial designer) evaluated all of the designs produced in both problem settings (See Section 4.3.1).

4.3 Instruments

4.3.1 Design Instruments

Surveys were conducted for both Problem Setting 1 and Problem Setting 2. Problem Setting 1 used the 30 source examples that were selected from near, medium and distant categories, which can be related with a workstation unit (Figure 2). For the near category product design examples were used, whereas for the medium category architecture design examples, and for the distant category, animal and nature examples were selected. Problem Setting 2 did not use any design instruments because the students were not given any examples so that they designed the workstation unit by using traditional design methods.

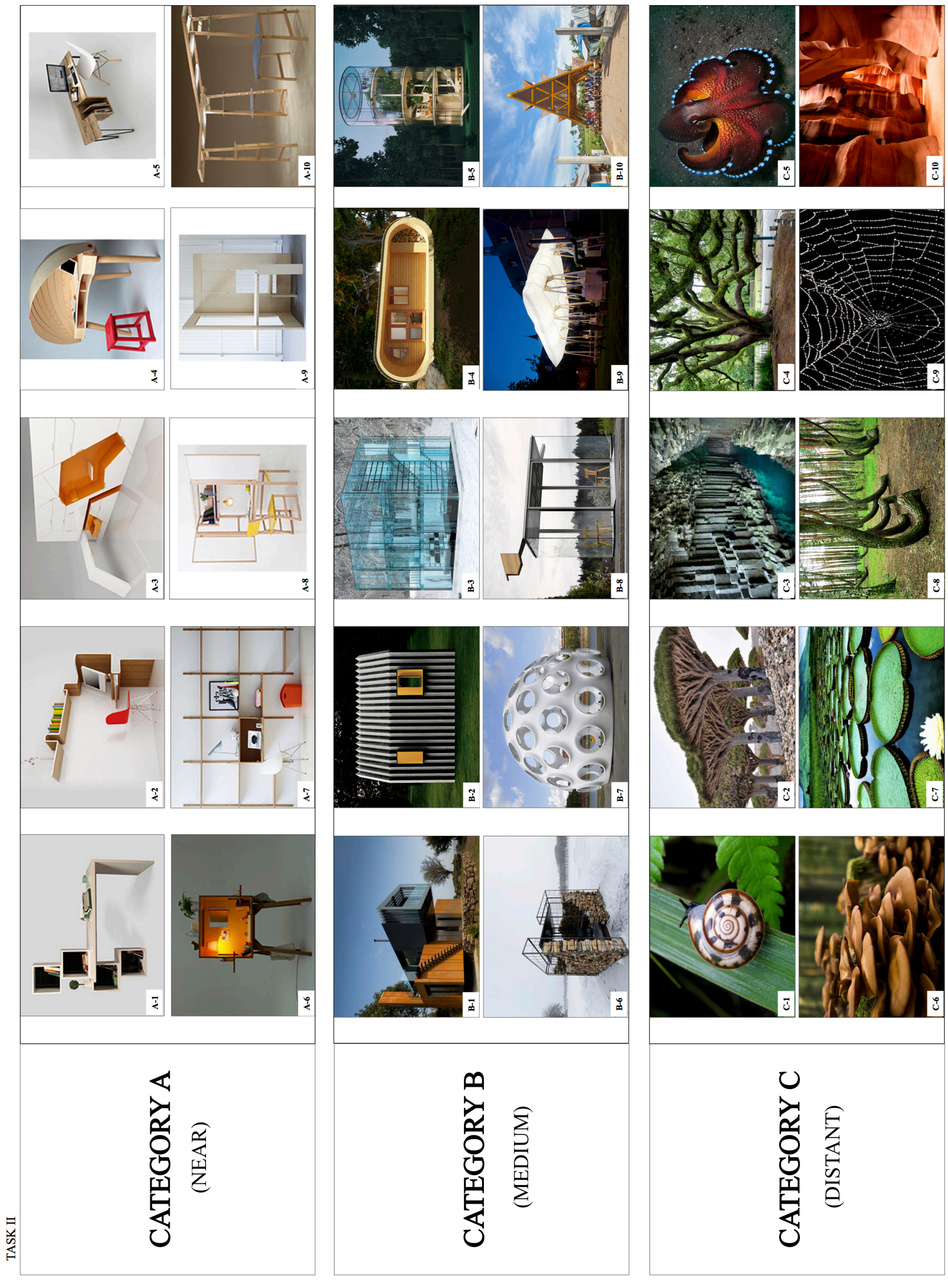

Figure 2. Selected thirty examples from three categories

The selection process of the examples was conducted based on the Delphi method. The Delphi method is the name that is given to a technique, developed through a series of studies by the RAND Corporation to come up with a technique to reach a consistent agreement between the experts (Dalkey & Helmer, 1963; Okoli & Pawlowski, 2004). It is preferred when a direct interaction is not needed in a group like in a debate, and it is effective in providing individual answers (Linstone & Turoff, 1975). There is no standard criterion concerning the selection of Delphi experts (Kaplan, 1971). Experts are selected and considered as eligible if they have a related background with the target issue (Pill, 1971). The Delphi method is conducted through two or more rounds. In the first round the experts are given the examples separately and they are required to rate the given examples (Dalkey & Helmer, 1963; Okoli & Pawlowski, 2004). After the first round the facilitator collects the answers and gives feedback to the experts. The experts receive a full feedback of all the answers from other experts including theirs and they can change their views and answers if they want to (Dalkey & Helmer, 1963). This process continues until there is a consensus between the participants (Dalkey & Helmer, 1963).

Within the framework of the thesis, the examples were selected in a two round process. Throughout the rating rounds the experts remain anonymous with each other. Anonymity is important in Delphi method, because it allows participants to express and change their thoughts without being influenced by other stands that have already been taken or used (Dalkey & Helmer, 1963).

According to the aim of this study, the experts were selected based on the following four criteria: 1- Knowledge and experience with the sustainability issues regarding the given problem, 2- Capacity and willingness, 3- Sufficient time to participate in the Delphi Method, 4- Effective communication skills (Adler & Ziglio, 1996).

In the first round, 90 examples, which are comprised of 30 examples from each category, were selected randomly. According to the Delphi method three independent experts (a LEED green associate architect, a LEED green associate interior architect and a product designer) were selected for the second round. The experts were selected according to the context of the given problem. The problem requires a previous knowledge of design, sustainability and product design. Therefore two of the experts were LEED green associates, which mean they have an up-to-date document and knowledge of the current requirements of green building regulations (See Section 3.3) (Cottrell, 2010; Knox, 2014). The experts were asked to rate 90 examples through a five point Likert scale (1- Poor, 2- Fair, 3- Average, 4- Good and 5- Excellent), considering the given problem of designing a workstation unit. In order to determine consensus among judges, two selection rounds were conducted. At the end of the second round examples were reduced to 30 images (10 source examples from each category) (Figure 2).

4.3.2 Mental Effort Assessment Instruments for Problem Setting 1 and Problem Setting 2

A mental effort assessment test was formed in order to evaluate the students' mental effort, which they put in during problem solving based on the use of analogical reasoning (See Appendix C). Mental effort refers to the perceived intensity of the effort spent during a task (Paas, 1992). Problems, which are familiar to the participants leads a decrease in the mental effort and problems, which are not familiar leads to increase the effort spent (Bandura, 1997; Pintrich & Schunk, 2002; Salomon, 1984). The measurement of mental effort is done in order to assess whether use of analogical reasoning have an impact on the mental effort of students or not. At the end of the tasks, in both Problem Setting 1 and 2 participants were given a mental effort test, which was adapted and modified from the studies by Paas, 1992 and Bratfisch, Borg & Dornic, 1972 (Figure 3). At the end of the tasks participants evaluated themselves with a 9-point Likert Scale (1- Low to 9- High, See Appendix C). Mental effort assessment test was given to participants in order to understand whether the use of analogical reasoning help the process and understanding of the given sustainable problem or not.

4.3.3 Creativity and Sustainability Assessment Instruments for the Problem Setting 1 and Problem Setting 2

In both Problem Settings 1 and 2 experts (same experts from the Delphi Method) (See Section 4.3.1) were given a creativity assessment survey, which was adapted from the study by Demirkan & Afacan, (2012) (Figure 3). The design creativity assessment survey is a Bipolar Likert-type scale and composed of 31 items (See Appendix D). The survey consists of individual creativity assessment items. Different to the study by Demirkan & Afacan, (2012), and based on the previous studies and literature, 31 items were chosen in this study (Demirkan & Afacan, 2012; Hasirci & Demirkan, 2009). All three experts were asked to rate each item on a bipolar scale for both Problem Settings 1 and 2.

Alongside the creativity assessment, a sustainability criteria evaluation survey was conducted (See Appendix E) (Figure 3). The sustainability criteria evaluation survey is composed of 10 sustainability criteria's related with the given problem (Moxon, 2012; Winchip, 2007). All three experts were asked to grade each criterion for both Problem Settings 1 and 2.The sustainability criteria evaluation survey is given to experts in order to measure the students' success findings.

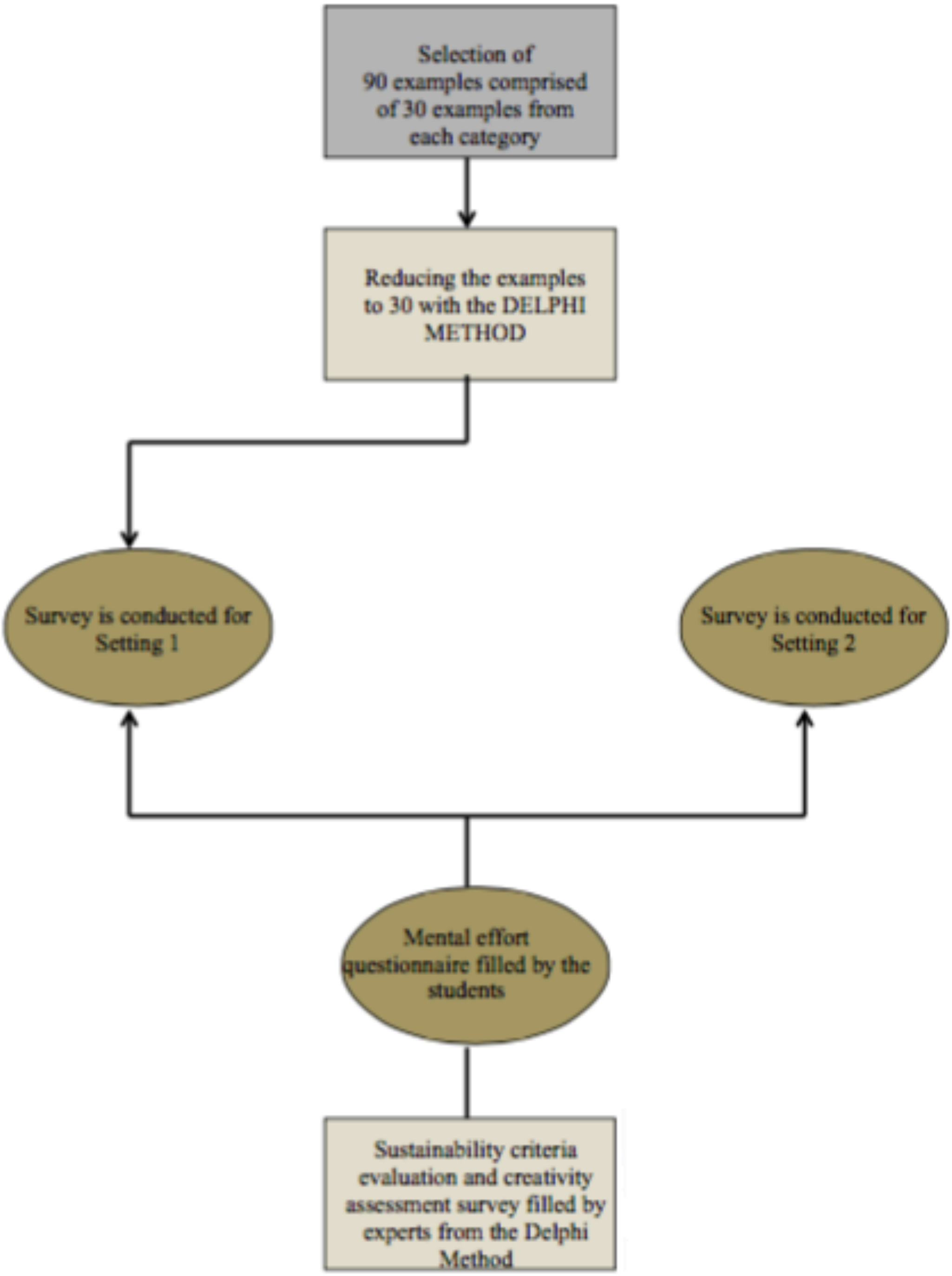

Figure 3. Process model of the research, drawn by the author, 2017.

CHAPTER V

RESULTS & DISCUSSIONS

5.1 Descriptive Analysis Results of Problem Setting 1

5.1.1 Task 1

In order to test the reliability of the results from the 30 examples rating, Cronbach's alpha value is used. Nunnally (1978) suggests that the Cronbach's alpha value should be above 0.7 for an internal consistency. Reliability of Task 1 was investigated and in this study the Cronbach's alpha value was found to be 0.778. According to the results Task 1 was found to hold an internal consistency (30 examples; Cronbach's alpha= 0.778). The results of Task 1 ratings from Problem Setting 1 are given in Table 2. From the results, it is indicated that in Task 1 in Problem Setting 1, the example with the highest rating is B1 (M= 4.21) (Figure 4), which is from the Category B (Medium Source Example Category).

Figure 4. Image of example B1

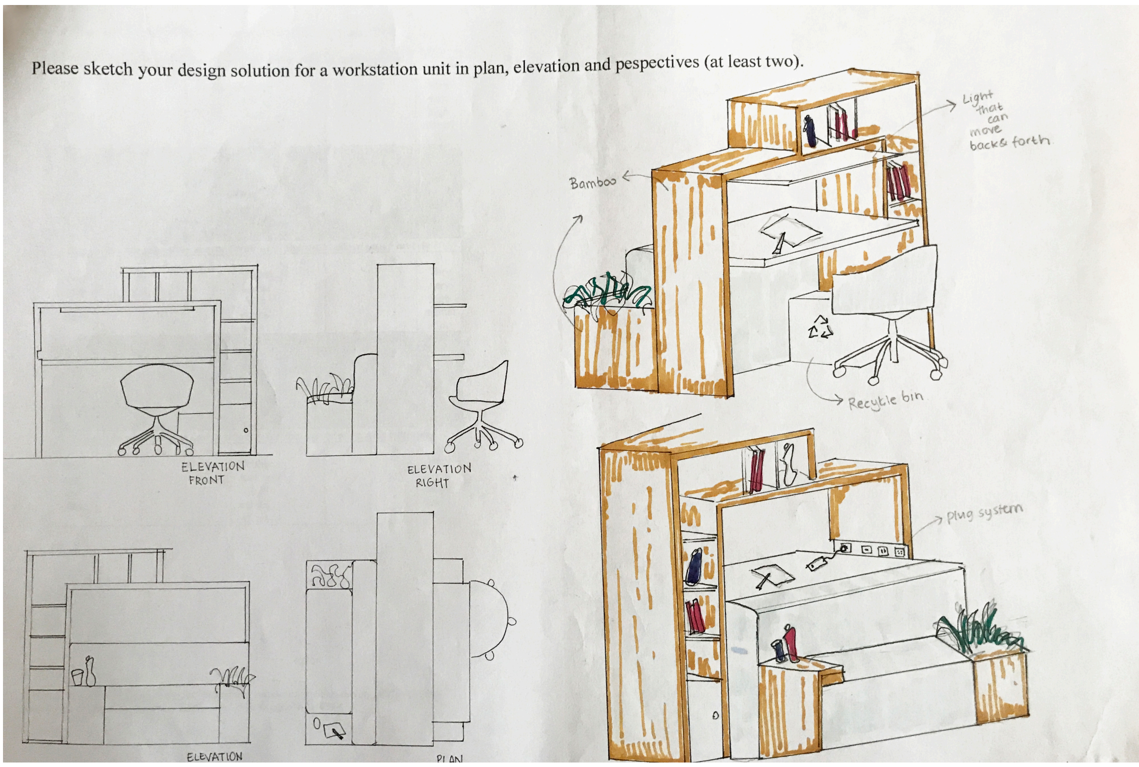

Figure 5. Design example of a student who chose B1 as a source example

Table 2. Appropriateness ratings of task 1 in the problem setting 1

Examples	Mean Values
A10	2,46
A4	2,72
A6	2,79
B9	2,86
B7	2,96
A1	3,04
A2	3,11
B6	3,16
B2	3,18
B10	3,19
B8	3,26
A8	3,32
C6	3,32
A9	3,38
A5	3,43
B3	3,47
C1	3,49
C7	3,50
C5	3,51
C8	3,54
C9	3,54
B4	3,60
A7	3,63
A3	3,63
C2	3,81
C3	3,84
B5	3,87
C4	3,89
C10	3,91
B1	4,21

5.1.2 Task 2

In Task 2, the participants were asked to select only one source example among the given thirty examples of the three source examples. The results of Task 2 are given in Figure 9. From the results it is indicated that in Task 2 from Problem Setting 1, the most selected example is A3 (M= 6.33), which is from the category A (Near Source Example Category) (Figure 6). A design example of a student is given in Figure 7 and Figure 8 in order to understand Task 2. According to the results 15.3% of the participants from Problem Setting 1 chose A3 as an example for designing a sustainable workstation unit.

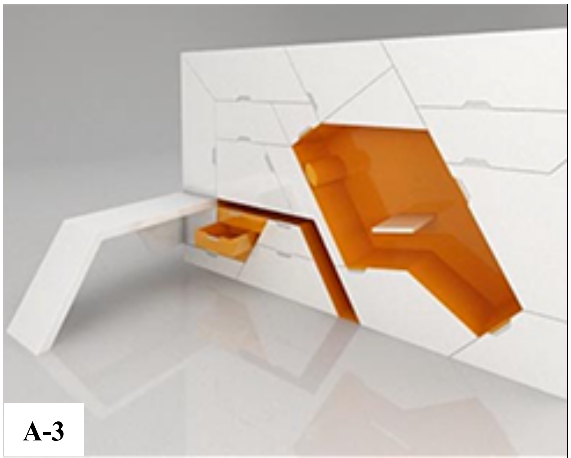

Figure 6. Image of example A3

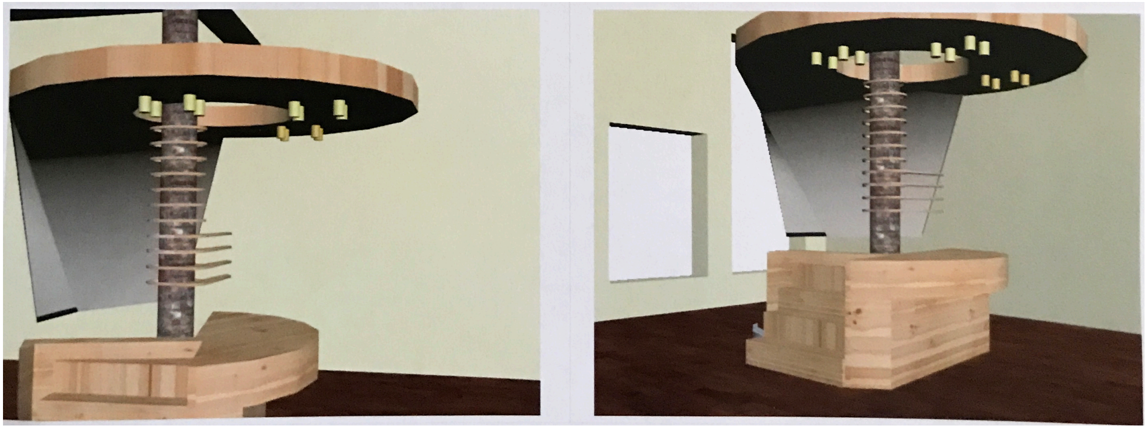

Figure 7. 3D drawings of a student who chose A3 as a source example

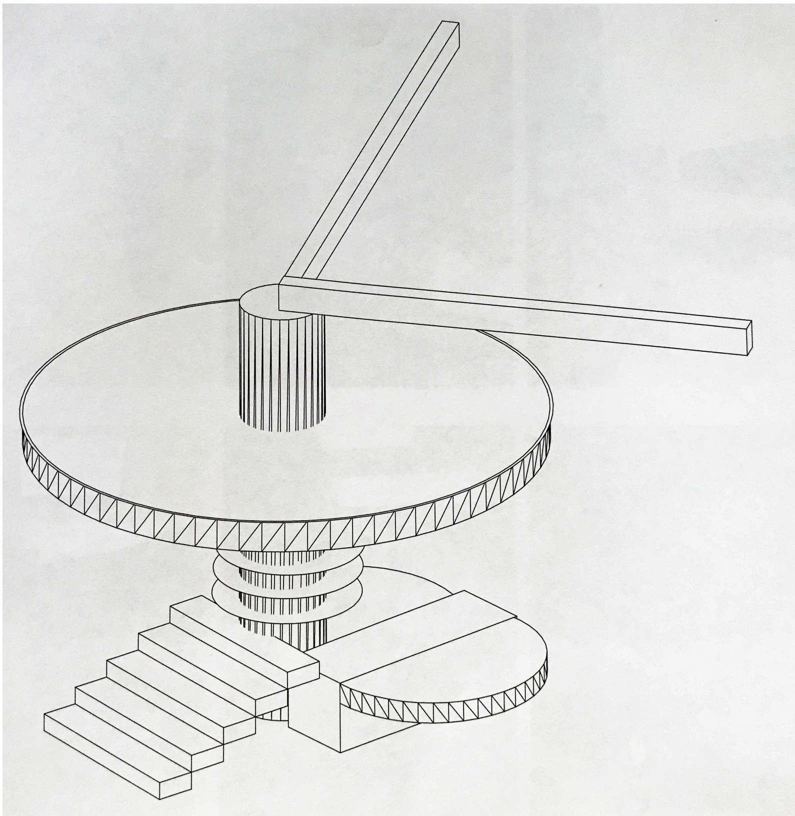

Figure 8. Perspective drawings of a student who chose A3 as a source example

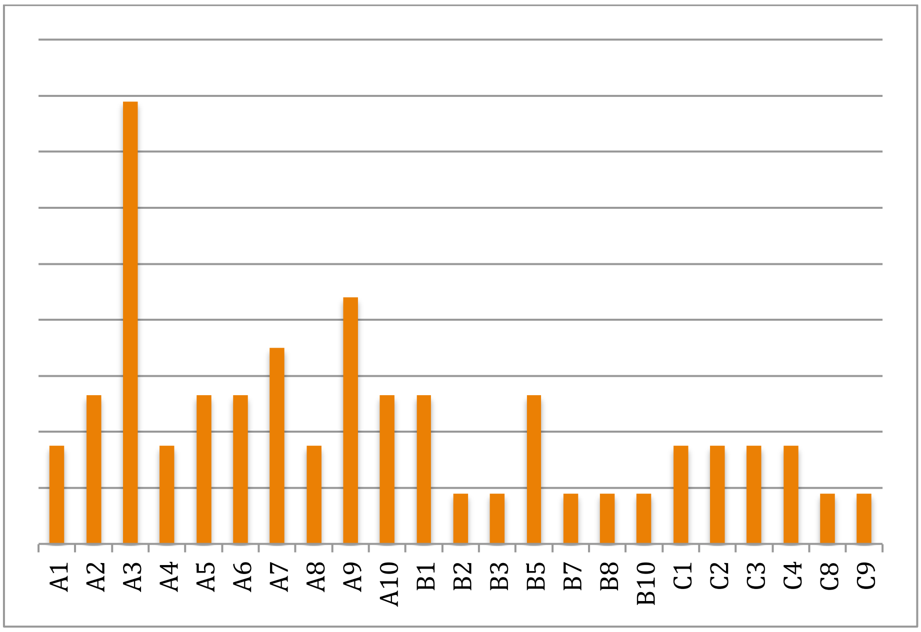

Figure 9. The percentages of example selection in bar graph format

5.1.3 Task 3

In Task 3 the participants were asked to select a design criterion from the 8-categeory items related with the example that they chose in Task 2. Some of the participants selected only one-design criterion, while some of them selected up to three design criteria even if it is specifically explained to select only one. The results of Task 3 are given in Table 3. The results indicate that in Problem Setting 1, the most commonly stated design criterion, from the items in the 8-category, is 'Function' (M= 2.19).

As given in Table 3, 45.6% of the participants from Problem Setting 1 chose 'Function' as a design criterion. Within all participants in Problem Setting 1, the participants who chose examples from category A (Near Source Example) (36 participants out of 57) mostly stated 'Function' as a design criterion (19 participants out of 36). An example of a student who chose a source example from category A, and 'Function' as a design criterion, is given in Figure 10 and 11 in order to understand Task 3. The second mostly stated design criterion among participants who chose examples from category A is 'Usability'. After refinement of the 8-category items, reliability of Task 3 was analyzed and found to have a high internal consistency with a Cronbach's alpha value of 0.974, therefore it can be stated that Task 3 indicates a high level of reliability (Nunnally, 1978).

Table 3. Percentages for 8-category items of problem setting 1

Categories	Frequency	Percentages
Aesthetics	7	12,3
Experience	1	1,8
Form	10	17,5
Function	26	45,6
Originality	1	1,8
Physical Property	2	3,5
Structure	5	8,8
Usability	5	8,8
Total	57	100,0

Figure 10. Source example selection of a student in problem setting 1, who chose function as a design criterion

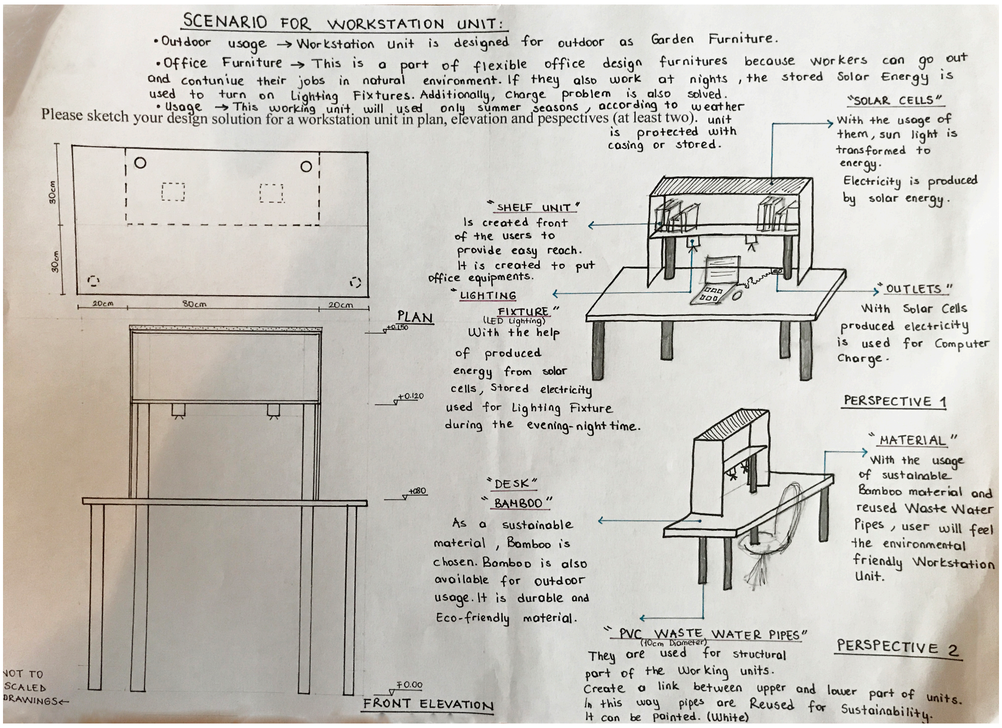

Figure 11. Design solution example of a student in problem setting 1, who chose function as a design criterion

5.1.4 Task 4

In Task 4 participants were told to design a workstation using analogy to the selected source example. Three independent judges (a LEED green associate architect, a LEED green associate interior architect, and a LEED green associate industrial designer) evaluated all of the designs produced in Task 4. The judges evaluated the designs with a sustainability evaluation criterion, which is adapted from the criteria given in the books of Moxon, (2012) and Winchip, (2007) (See Appendix E). The sustainability evaluation form is composed of, 10 criteria in the context of the given problem, each of which has a grading of 10 (Table 4). Alongside with the sustainability criteria evaluation, the judges also evaluated the designs produced in Task 4 with a creativity assessment survey, adapted from the study by Demirkan & Afacan, (2012) (See Section 4.3.3) (See Appendix D). The student who has the highest grade in Problem Setting 1 according to the evaluations of the experts, have chosen C8 as a source example and form as a design criterion (Figure 12 and 13).

Table 4. Sustainability evaluation criteria

	Sustainability Evaluation Criteria	Grading	Total
1	Application of new technologies/eco technologies	10	
2	A future focused strategy (a holistic approach)	10	
3	Use of recycled materials	10	
4	Use of non-toxic materials	10	
5	Use of locally sourced materials	10	
6	Use of energy-efficient system	10	
7	Provide space to promote healthy working	10	
8	Durability	10	
9	Flexible design/modularity	10	
10	Simple design (avoidance of over-complicated design)	10	
			100

Figure 12. Source example selection of the student with the highest grade in problem setting 1

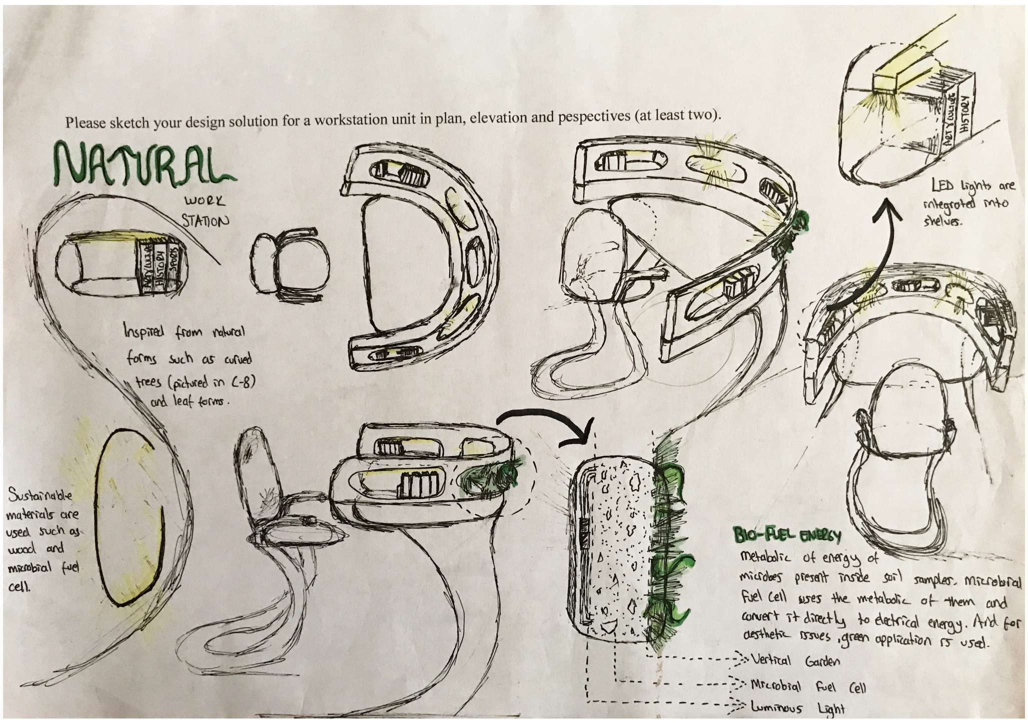

Figure 13. Design solution example of the student with the highest grade in problem setting 1

5.2 Descriptive Analysis Results of Problem Setting 2

5.2.1 Task 1

The requirements of Task 1 in Problem Setting 2 were the same as Task 3 in Problem Setting 1. The participants were asked to select a design criterion from the 8-categeory items. Some of the participants selected only one design criterion, while some of them selected two design criteria. The results of the Task 1, given in Table 5 indicate that same as in Problem Setting 1, the most commonly stated design criterion from 8-category items is 'Function' (M= 2.03). An example of a student, who chose 'Function' as a design criterion, is given in Figure 14 in order to understand Task 1. As given in Table 5, 49.2% of the participants from Problem Setting 2 chose 'Function' as a design criterion. After refinement of the 8-category items, reliability of Task 1 was analyzed and the survey was found to have a high internal consistency with a Cronbach's alpha value of 0.994. Therefore it can be stated that Task 1 indicates high level of reliability (Nunnally, 1978).

Table 5. Percentages for 8-category items of problem setting 2

Categories	Frequency	Percentages
Aesthetics	5	8,5
Form	8	13,6
Function	29	49,2
Originality	3	5,1
Physical Property	7	11,9
Structure	2	3,4
Usability	5	8,5
Total	59	100,0

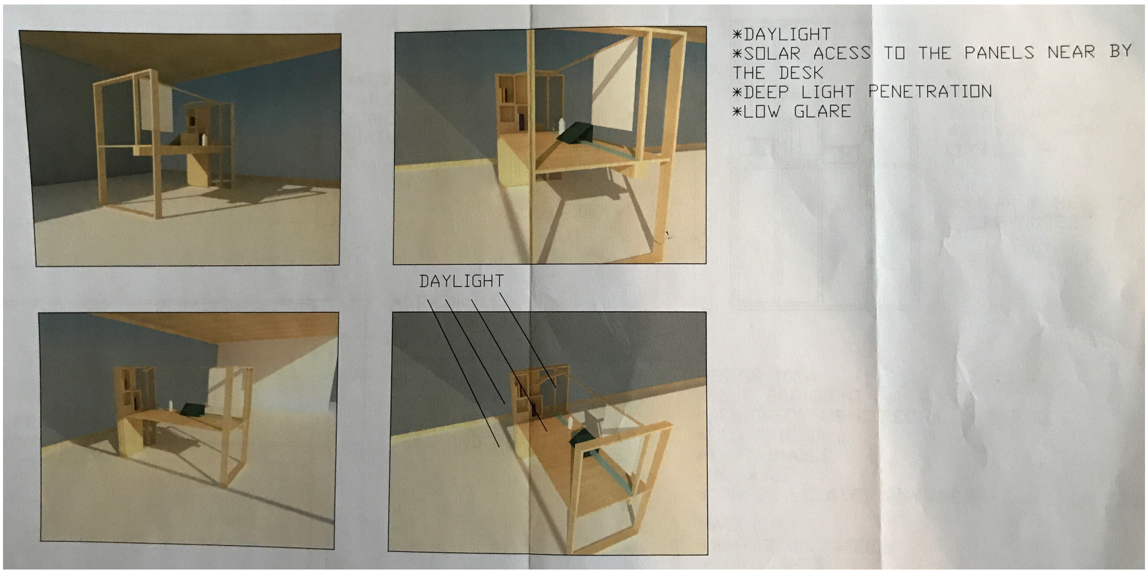

Figure 14. Design solution example of a student in problem setting 2, who chose function as a design criterion

5.2.2 Task 2

The requirements of Task 2 in Problem Setting 2 were the same as Task 4 in Problem Setting 1. The participants were told to design a workstation using traditional design methods. The same three independent judges (a LEED green associate architect, a LEED green associate interior architect, and a LEED green associate industrial designer) evaluated all of the designs produced in Task 2 with the same sustainability evaluation criterion and creativity assessment (See Section 4.3.3 and 5.1.4). The example of the student, who has the highest grade in Problem Setting 2, is given in Figure 15.

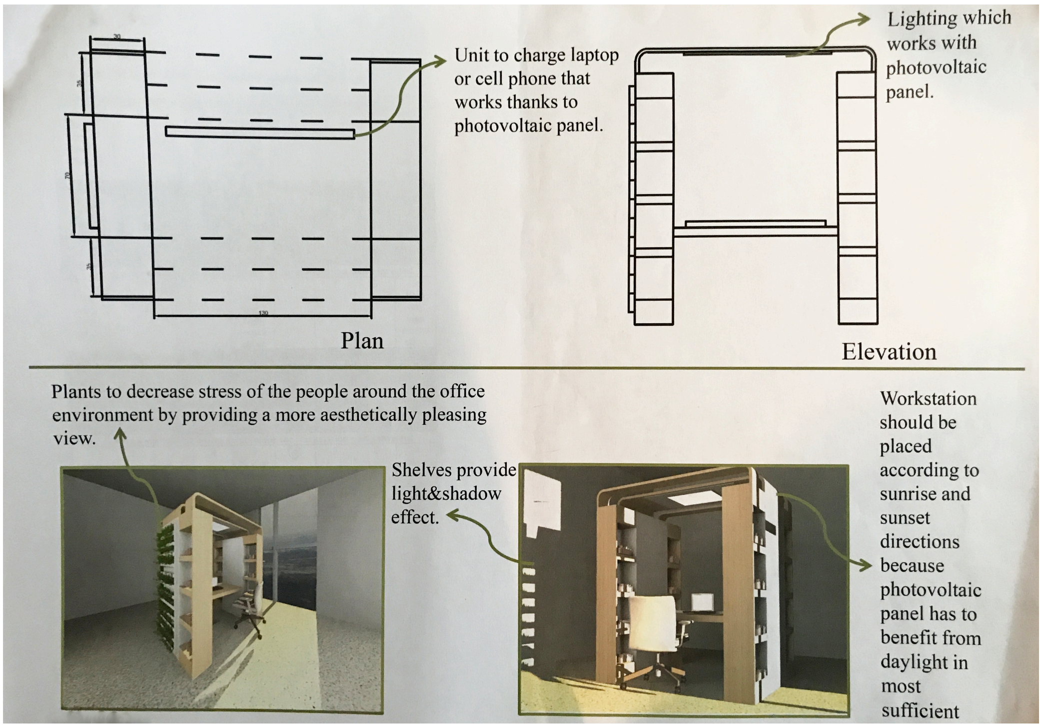

Figure 15. Design solution example of the student with the highest grade in problem setting 2

5.3 Comparison Between Problem Setting 1 and Problem Setting 2

In order to determine the differences between participants in Problem Setting 1 and Problem Setting 2 the findings of the study were analyzed in 4 parts; 1- Success Findings, 2- Mental Effort Findings, 3- Stated Design Criteria Findings, and 4- Creativity Findings. In all four parts, in order to analyze and evaluate the data in the study, descriptive analysis tests were conducted (Argyrous, 2011). In order to determine whether there is a significant difference between participants in Problem Setting 1 and participants in Problem Setting 2 for all four parts, independent samples t-test is conducted (Argyrous, 2011). For the fourth part, namely creativity findings, in order to determine the underlying similarities between variables, exploratory factor analysis was used.

5.3.1 Success Findings

Success findings are examined through a sustainability criteria evaluation, which were filled by the experts from the Delphi method (See Section 4.3.1). In both Problem Setting 1 and Problem Setting 2, the final designs of the participants were evaluated through this sustainability criteria evaluation survey (See Appendix E). All of the final designs of the participants were evaluated through 10 sustainability criteria and given a score out of 10 (Figure 16) (See Section 4.3.3). For each student the results were summed up and a final grade was generated.

To determine whether there is a significant difference between participants in Problem Setting 1 and participants in Problem Setting 2, an independent samples t-test is conducted with the final grades. According to independent samples t-test results, the success findings of participants in Problem Setting 1 and Problem Setting 2 are not equal at 95% significance level (Figure 16). So there is a significant difference between students' grades ($t= -3.138$, $df= 114$, $p= 0.002$), (Setting 1 $M = 1.28$, $SD= 0.453$, Setting 2 $M = 1.56$, $SD= 0.501$) which confirms H1: "There is a statistically significant success difference (in problem solving) between student groups based on the use of analogical reasoning".

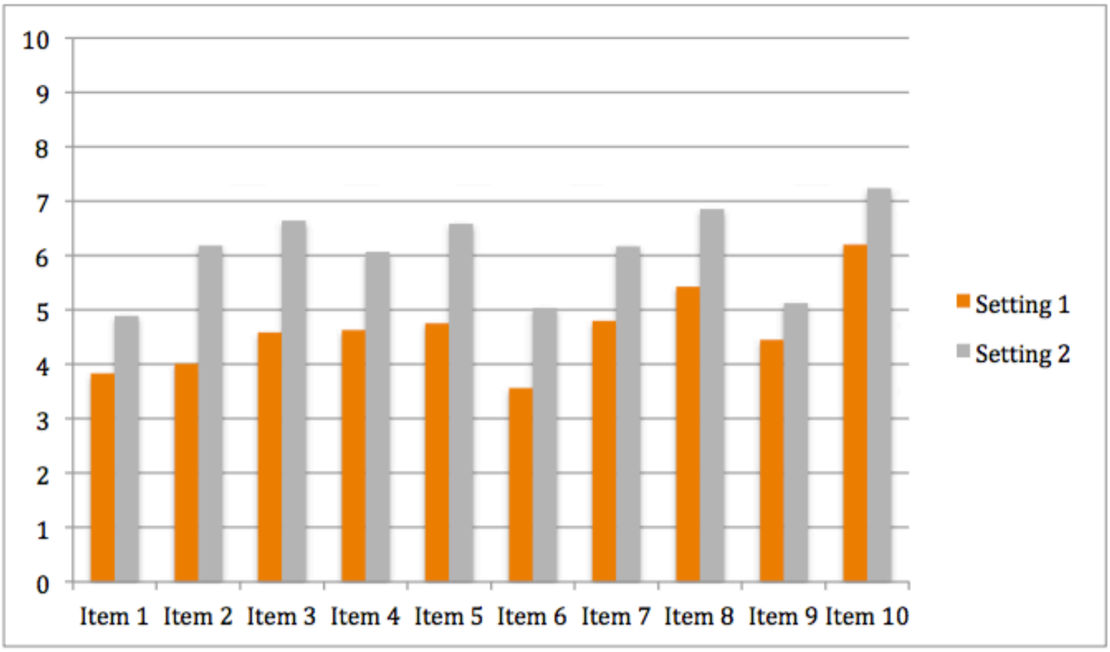

Figure 16. Success findings of problem setting 1 and problem setting 2 in a bar graph format

5.3.2 Mental Effort Findings

The effort that participants put in during the process of problem solution was self assessed with a mental effort questionnaire (See Appendix C). In order to determine whether there is a significant difference in students' mental efforts between Problem Setting 1 and Problem Setting 2, an independent samples t-test is conducted. For all 5 statements in the mental effort questionnaire the test was conducted separately (Figure 17). According to the results there is no statistically significant difference between participants in Problem Setting 1 and Problem Setting 2, regarding mental effort (Table 6) in 4 questionnaire items out of 5. The results indicated that there is a significant difference only in the second item, which is 'To understand the requirements of the workstation unit I invested' ($p= 0.032$). Therefore H2: "There is a statistically significant mental effort difference (in problem solving) between student groups based on the use of analogical reasoning" is rejected. The reliability of the mental effort survey was investigated and in result the survey was found to hold an internal consistency with Cronbach's alpha value 0.857, therefore it can be stated that the mental effort survey indicates high level of reliability (Nunnally, 1978).

Table 6. Independent samples t-test results for mental effort

	Items	t	df	P value	Setting 1M	SD	Setting 2M	SD
1	**Sustainable problem solving process for a workstation unit requires**	0.045	114	.964	6.351	.329	6.341	.504
2	**To understand the requirements of the workstation unit I invested**	-2.167	114	.032	5.181	.794	5.901	.797
3	**To analyze resources/the examples of the workstation unit I invested**	-1.013	114	.313	5.651	.541	5.951	.644
4	**To synthesize resources/the examples of the workstation unit I invested**	-0.768	114	.444	5.811	.674	6.031	.508
5	**To achieve a sustainable design solution for the workstation unit I invested**	-0.005	114	.996	6.541	.364	6.541	.546

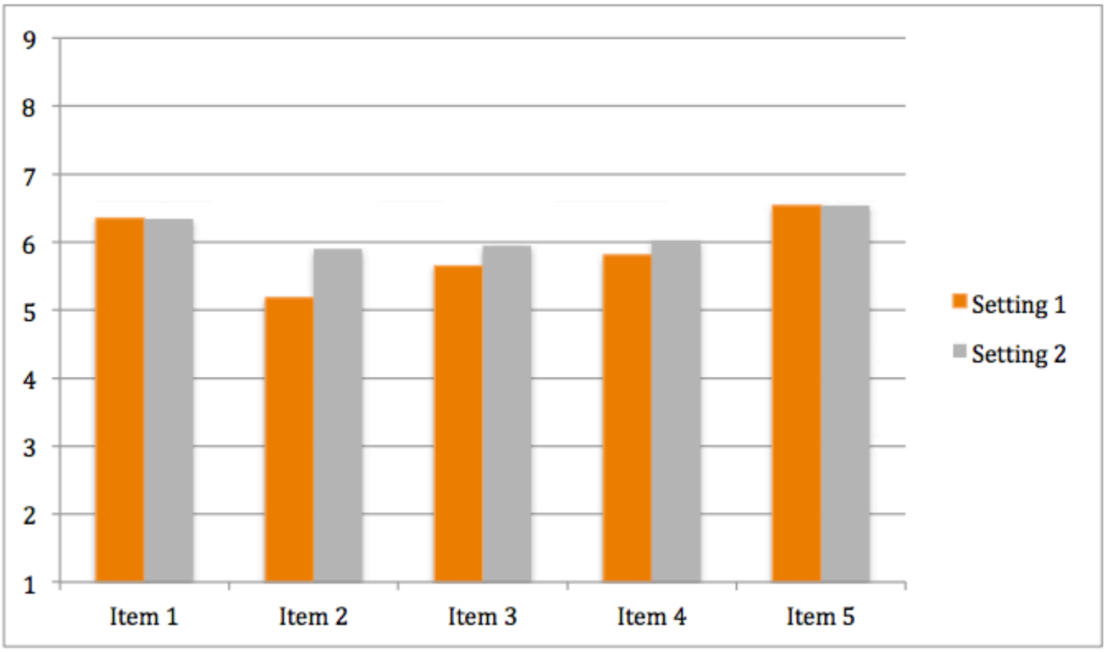

Figure 17. Mental effort findings of problem setting 1 and problem setting 2 in a bar graph format

5.3.3 Stated Design Criteria Findings

To determine whether there is a significant difference between participants in Problem Setting 1 and participants in Problem Setting 2 regarding stated design criteria an independent samples t-test is conducted (Figure 18). According to the independent samples t-test results there is no statistically significant difference between participants in Problem Setting 1 and Problem Setting 2 regarding stated design criteria ($t= -0.633$, $df= 114$, $p= 0.528$), (Setting 1 $M = 4.12$, $SD= 1.937$, Setting 2 $M = 4.34$, $SD= 1.738$). In both Problem Setting 1 and Problem Setting 2 ‘Function’ is the most stated design criterion (Figure 18). In both Problem Setting 1 and Problem Setting 2 the second most selected design criterion, after ‘Function’, is ‘Form’ (Figure 18). According to the results it can be stated that H3: “There is a statistically significant stated design criteria difference (in problem solving) between student groups based on the use of analogical reasoning” is rejected.

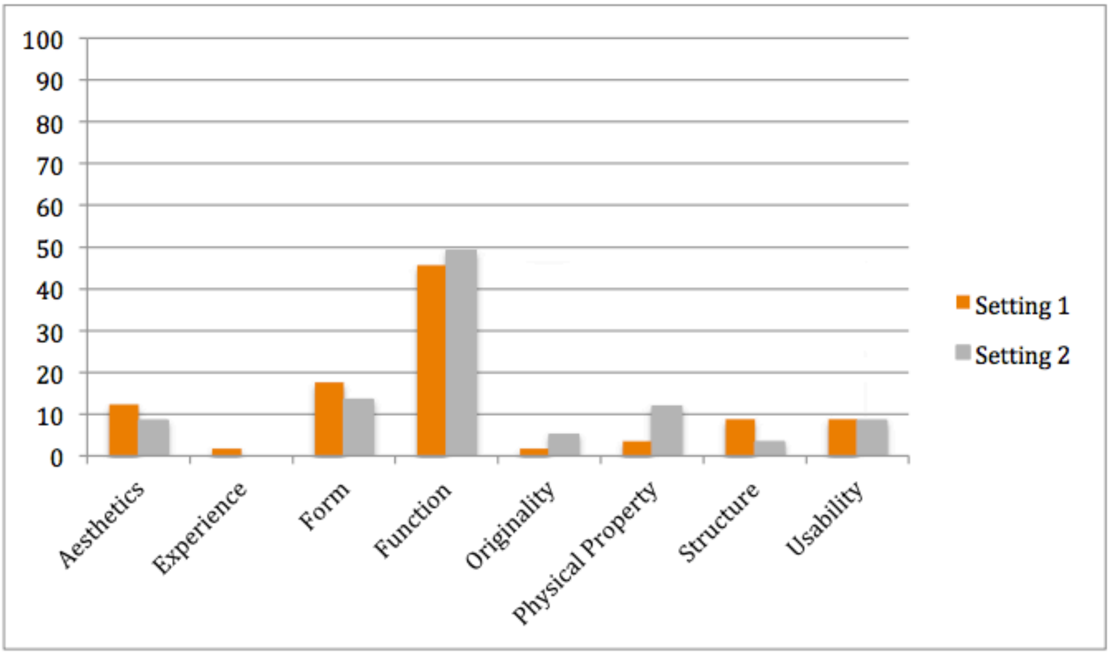

Figure 18. Stated design criteria percentages of problem setting 1 and problem setting 2 in a bar graph format

5.3.4 Creativity Findings

5.3.4.1 Descriptive Analysis

Before conducting further tests related with creativity findings, descriptive analysis was implemented for both Problem Setting 1 and Problem Setting 2. Results of the analysis for Setting 1 showed that the mean scores for the design creativity items ranged from 2.81 to 3.36 with a standard deviation from 0.643 to 0.923; while in Setting 2 the mean scores for the design creativity items ranged from 2.52 to 3.25 with a standard deviation from 0.625 to 1.013.

5.3.4.2 Factor Analysis

In order to determine the relationship between measured variables, exploratory factor analysis was carried out with 23 items via SPSS 21.0 package software. Before conducting the factor analysis test, the reliability of the results was measured. In order to determine whether the correlation between the 31 creativity items is reliable a reliability test was conducted. According to the results, all correlation scores of the items for both settings were above 0.90. So it can be stated that there is a high internal consistency between 31 creativity items both for Problem Setting 1 and Problem Setting 2. Before conducting the factor analysis test, due to the ceiling and floor effects, 8 items were eliminated.

The elimination was made due to the items scores. The items scoring lower than 0.50 were omitted in the factor analysis. This is because a score of 1.00 represents a perfect correlation, while a score under 0.50 represents a weak correlation between the items (Argyrous, 2005). In order to determine the factors for both settings, a rotated component matrix was constructed. Using this matrix, for both Problem Setting 1 and Problem Setting 2 two factors were calculated with 89.01% and 83.98% variances respectively (Table 7 and 8). According to the results the primary factor in Problem Setting 1, which formed 83.817% of the variance, was composed of 17 items (Table 9). Similar to the study by Demirkan & Afacan, (2012) these items were related to the novelty characteristics (Infrequent, unknown, unusual, rare, unique, new, original, eccentric, different, novel, unconventional, extraordinary, zippy, exciting, pleasant, evolving and limited) of the design. Therefore Factor 1 was named novelty. The second factor in Problem Setting 1 formed 5.196% of the total variance and was composed of 6 items (Table 10). Similar to the study by Demirkan & Afacan, (2012) these 6 items were related to the elaboration characteristics (Sensible, balanced, coherent, deliberate, polished and delighted) of the design, therefore the second factor was named elaboration.

According to the results the primary factor in Problem Setting 2, which formed 79.569% of the variance, was composed of 18 items (Table 11). Similar to Problem Setting 1, the items of Factor 1 in Problem Setting 2 were related to the novelty characteristics (Unusual, rare, unique, extraordinary, novel, different, original, new, zippy, unknown, exciting, eccentric, infrequent, delighted, pleasant, evolving, unconventional and limited) of the design.

Therefore Factor 1 was named novelty. The second factor in Problem Setting 2 formed 4.418% of the total variance and was composed of 5 items (Table 12). These 5 items were related to the elaboration characteristics (Balanced, coherent, deliberate, polished and sensible) of the design, therefore the second factor was named elaboration.

Table 7. Summary of factor 1 and factor 2 for problem setting 1

Factor	Scale	Eigen Value	Variance %	Cumulative %	Mean Value
1	**Novelty**	19.278	83.817	83.817	3.26
2	**Elaboration**	1.195	5.196	89.013	3.00

Table 8. Summary of factor 1 and factor 2 for problem setting 2

Factor	Scale	Eigen Value	Variance %	Cumulative %	Mean Value
1	**Novelty**	18.301	79.569	79.569	3.08
2	**Elaboration**	1.016	4.418	83.987	2.65

Table 9. Items of factor 1 (novelty) in problem setting 1

Items of Factor 1: Novelty	Loadings
1 Infrequent/Frequent	0.881
2 Unknown/Familiar	0.879
3 Unusual/Usual	0.848
4 Rare/Standard	0.836
5 Unique/Ordinary	0.832
6 New/Old	0.822
7 Original/Commonplace	0.819
8 Eccentric/Conventional	0.814
9 Different/Typical	0.812
10 Novel/Predictable	0.810
11 Unconventional/Conventional	0.799
12 Extraordinary/Regular	0.779
13 Zippy/Bland	0.732
14 Exciting/Dull	0.686
15 Pleasant/Unpleasant	0.662
16 Evolving/Not Evolving	0.657
17 Limited/Unlimited	0.592
Cronbach's Alpha	0.992

Table 10. Items of factor 2 (elaboration) in problem setting 1

Items of Factor 2: Elaboration	Loadings
1 Sensible/Unrealistic	0.873
2 Balanced/Unbalanced	0.856
3 Coherent/Jumbled	0.822
4 Deliberate/Accidental	0.820
5 Polished/Rough	0.813
6 Delighted/Horrified	0.721
Cronbach's Alpha	0.976

Table 11. Items of factor 1 (novelty) in problem setting 2

Items of Factor 1: Novelty	Loadings
1 Unusual/Usual	0.868
2 Rare/Standard	0.860
3 Unique/Ordinary	0.843
4 Extraordinary/Regular	0.831
5 Novel/Predictable	0.811
6 Different/Typical	0.805
7 Original/Commonplace	0.804
8 New/Old	0.804
9 Zippy/Bland	0.797
10 Unknown/Familiar	0.794
11 Exciting/Dull	0.790
12 Eccentric/Conventional	0.785
13 Infrequent/Frequent	0.741
14 Delighted/Horrified	0.691
15 Pleasant/Unpleasant	0.667
16 Evolving/Not Evolving	0.637
17 Unconventional/Conventional	0.544
18 Limited/Unlimited	0.503
Cronbach's Alpha	0.990

Table 12. Items of factor 2 (elaboration) in problem setting 2

Items of Factor 2: Elaboration	Loadings
1 Balanced/Unbalanced	0.837
2 Coherent/Jumbled	0.806
3 Deliberate/Accidental	0.800
4 Polished/Rough	0.765
5 Sensible/Unrealistic	0.714
Cronbach's Alpha	0.954

5.3.4.3 Independent Samples T-test

In order to determine whether there is a significant difference between participants in Problem Setting 1 and participants in Problem Setting 2 regarding creativity an independent samples t-test is conducted (Figure 19). According to the independent samples t-test results there is no statistically significant difference between participants in Problem Setting 1 and Problem Setting 2 regarding creativity in 29 items out of 31. According to the results it can be stated that Hypothesis 3 is rejected. There is a statistically significant difference between items Coherent and Unconventional. ($t= 3.285$, $df= 114$, $p= 0.001$), (Setting 1 $M = 3.014$, $SD= .839$, Setting 2 $M = 2.533$, $SD= .734$) ($t= 3.134$, $df= 114$, $p= 0.002$), (Setting 1 $M = 3.301$, $SD= .789$, Setting 2 $M = 2.850$, $SD= .759$).

According to the results it can be stated that H4: “There is a statistically significant creativity difference (in problem solving) between student groups based on the use of analogical reasoning” is rejected.

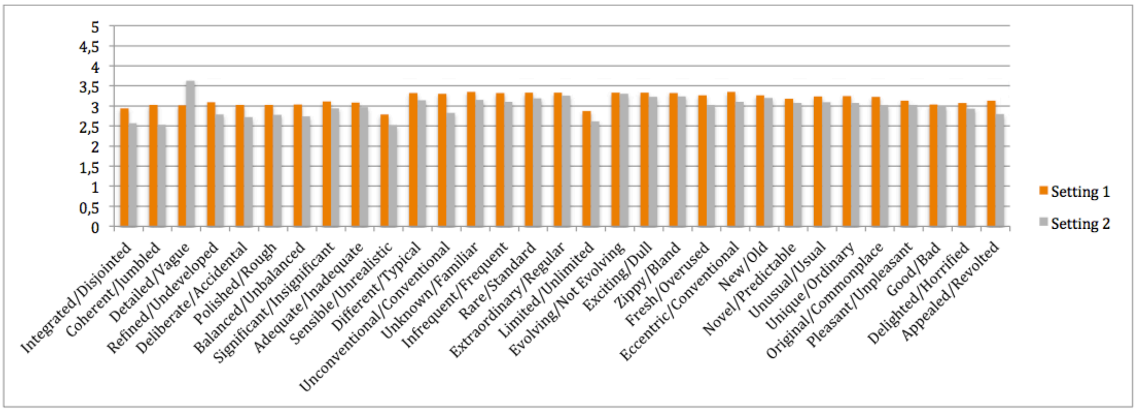

Figure 19. Creativity findings of problem setting 1 and problem setting 2 in a bar graph format

5.4 Overall Discussion of the Findings

When all the findings are taken into consideration, it can be said that contrary to the predicted results there are no major differences between student groups who are using analogical reasoning and traditional design methods in sustainable problem solving. In the scope of the literature review, it is seen that the use of analogical reasoning improves the solution and helps the process of problem solving (Casakin, 2004; Casakin & Goldschmidt, 1999; Cubukcu & Dundar, 2007; Gick & Holyoak, 1980; Ozkan & Dogan, 2013; Verstijnen, Wagemans, Heylighen & Neuckermans, 1999). In this study, it was found that there is no statistically significant difference in the solution process of the given sustainability problem.

In the literature review, it is seen that there is a positive relationship between success and creativity (Cubukcu & Dundar, 2007; Kalogerakis et. al., 2010). The H1: "There is a statistically significant success difference (in problem solving) between student groups based on the use of analogical reasoning" and H4: "There is a statistically significant creativity difference (in problem solving) between student groups based on the use of analogical reasoning" were formulated according to the literature review based on the success and creativity differences between student groups who are using analogical reasoning and traditional design methods. However, the results indicated that while the success findings of the students differ (Figure 16), there is no difference between students in both Problem Setting 1 and Problem Setting 2 regarding creativity (Figure 16). Therefore H1 is not rejected, while H4 is rejected according to the results.

When the 10 criteria of the sustainability criteria evaluation are taken into consideration, there is a slightly more difference in the second and the third criteria, which are ‘A future focused strategy’ and ‘Use of recycled materials’ respectively (Figure 16) (See Appendix E). Opposite to the literature, which indicates that the use of analogical reasoning is beneficial for the quality of the design and therefore students’ success (Casakin, 2004; Casakin & Goldschmidt, 1999; Cubukcu & Dundar, 2007; Verstijnen, Wagemans, Heylighen & Neuckermans, 1999), in this study the success findings of students in Problem Setting 2 found to be higher than the success findings of students in Problem Setting 1. When the 31 items in the creativity assessment survey are taken into consideration, there is no significant difference between students in problem Setting 1 and students in Problem Setting 2 (Figure 19) (See Appendix D). In contrary to the literature, which indicates that use of analogical reasoning in an efficient way increases the creativity of the student, according to the results of the study it can be said that there is no difference between students in Problem Setting 1 and students in Problem Setting 2 regarding creativity (Cubukcu & Dundar, 2007; Kalogerakis et. al., 2010). There is only a significant difference between the 2nd and the 12th design creativity items, which are ‘Coherent/Jumbled’ and ‘Unconventional/Conventional’ respectively.

When the H2: " There is a statistically significant mental effort difference (in problem solving) between student groups based on the use of analogical reasoning” is examined, it has been found that there is no significant difference between students in Problem Setting 1 and students in Problem Setting 2. According to the results regarding mental effort, students in both Problem Setting 1 and Problem Setting 2, found the given sustainability problem slightly hard to solve, but they differed in understanding the requirements of the given problem. When the 5 items in the mental effort questionnaire are taken into consideration there is a significant difference in the second item, which is ‘To understand the requirements of the workstation unit I invested’ (Table 6 and Figure 17) (See Appendix C). In contrary to the literature, which indicates that use of analogical reasoning in problem solving eases the process of solution (Gick & Holyoak, 1980; Herstatt & Kalogerakis, 2005), in this study the results indicate that students in Problem Setting 2 understood the requirements of the sustainability problem easier than students in Problem Setting 1.

The results indicated that there is no difference between students in both Problem Setting 1 and Problem Setting 2 regarding stated design criteria. When the H3: " There is a statistically significant stated design criteria difference (in problem solving) between student groups based on the use of analogical reasoning” is examined the most selected design criterion is ‘Function’ (Table 3 and 5). When the 8-category items are examined the most selected design criterion in both Problem Setting 1 and Problem Setting 2 is ‘Function’ and the second most selected item in both settings is ‘Form’ (Figure 18) (See Appendix A and B). Students whether using analogical reasoning or traditional design methods stated, ‘Function’ as a design criterion and solved the problem accordingly (Figure 10, 11 and 14).

At the end of the study, the experts from the Delphi method reviewed all of the outcomes from both Problem Setting 1 and Problem Setting 2 (See section 4.3.1). In contrary to the studies by Casakin, 2004; Casakin & Goldschmidt, 1999; Cubukcu & Dundar, 2007; Verstijnen, Wagemans, Heylighen & Neuckermans, 1999, the success results of the students who are using traditional design methods (Problem Setting 2) are higher than the students who are using analogical reasoning (Problem Setting 1) (Figure 16).

CHAPTER VI

CONCLUSION

Analogy is a procedure of transferring gained knowledge and information from previously experienced problems and using this knowledge in the development and solution of a new problem (Gentner, 1998; Gentner & Smith, 2012; Gick & Holyoak, 1980; Holyoak & Thagard, 1989). In order to use analogy in a problem, a mutual relation system should be formulated between the two problems (Gentner & Smith, 2012). Analogical reasoning is the name given to the cognitive process of using analogy. The usage of analogical reasoning has an impact on student's problem solving and design decisions (Gick & Holyoak, 1980; Ozkan & Dogan, 2013). In recent years analogical reasoning has been widely used in every stages of design education (Gentner & Toupin 1986; Ozkan & Dogan, 2013).

Sustainability is an uprising concept, which can be interpreted differently according to the major of use. In recent years the concept of sustainability is expanded with concepts such as energy and environmental preservation, water and energy efficiency (Fisher &

McAdams, 2015). Sustainability is a widely used concept among design education (Bala, 2010). It is suggested that sustainability should not be just a concept, which is taught in design education by choice. It should be combined into the entire curriculum of design education as an essential ingredient (Bala, 2010; Gürel, 2010; Shephard, 2008). Students should be encouraged to take courses from environmental studies in order to increase their awareness of sustainability (Fisher & McAdams, 2005; Smith-Sebasto, 1995).

In order to manage integrating sustainability into design education, and facilitate the process of sustainability learning it is considered that analogical reasoning can be used. Analogical reasoning is used as help for problem solving, learning and development process. In this respect, it is considered that use of analogical reasoning, as a tool in design education can be effective for the sustainable problem solving process. In order to understand the role of analogical reasoning in sustainable problem solving, two problem settings were formed. In Problem Setting 1, students used analogical reasoning, and in Problem Setting 2 students used traditional design methods in order to solve the sustainability design problem. The given problem is to design a sustainable workstation unit, which composes of a desk, a shelf, and a lighting element (See Appendix A and B).

According to the statistics, and on the contrary to the predicted results, it is found that there are no statistically significant differences between students in Problem Setting 1 and Problem Setting 2 regarding mental effort, stated design criteria and creativity. When H1: “There is a statistically significant success difference (in problem solving) between student groups based on the use of analogical reasoning” is examined, it is found that there is a significant difference between students’ success findings. Opposite to the literature review the success findings of the students in Problem Setting 2 who used traditional design methods were found to be higher than the students in Problem Setting 1 who used analogical reasoning to solve the given sustainable problem.

In conclusion, in this research the role and importance of analogical reasoning in sustainable problem solving is evaluated from the students’ perspective. This research is a contribution to both literature, and to designers and educators who want to integrate sustainability into design education and use analogical reasoning. Furthermore, this research has an importance in terms of using analogical reasoning for solving a sustainable design problem. Moreover, since the Delphi method is used in this study in order to select the examples, used in analogical reasoning, it could potentially lead to an increase in this method and bring a more reliable and appropriate approach to the process of analogical reasoning and sustainable problem solving.

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APPENDICES

APPENDIX A

SETTING 1- CONSISTS OF FOUR TASKS

27.02.2017

Research Homework

HW

A Sustainable Workstation Unit

The provision of sustainable built environments is not only matter of interior design, but also an essential material design and furnishing concern to enhance the quality of human life for safe, healthy and comfortable spaces. A high quality furniture design contributes positively to the wellbeing of the individual through the efficient use of site, energy, water, materials and resources of the general environment.

In this respect, your research homework is to design a sustainable workstation unit based on the IAED 342 course theoretical framework. A workstation unit is defined as an area that has the equipment needed for one person to do a particular job. The equipment in this problem includes a desk, a shelf and a lighting element. There are no dimensional considerations regarding the equipment. You are working individually. 30 visual images in three categories are given to you to assist you during the design process. Your design process is composed of four tasks:

> **Task1-** Evaluate the usefulness of each visual image in three categories as a source domain for designing a sustainable table unit.
>
> **Task 2-** Choose ONLY ONE visual image from the categories to design a sustainable workstation unit.
>
> **Task 3-** Choose ONLY ONE design criterion, which is the most appropriate for your design.
>
> **Task 4-** Sketch your design solution for a sustainable workstation unit in plan, elevation and perspectives (at least two) in the given A3 sheet.

Your DESIGN must be your own analyses, so should not be copied from any Internet source. Unauthorized aid or assistance on any form of academic work (Cheating), copying another work and adopting as same as one's own work (Plagiarism) and untruth statements are not allowed (Falsification) and treated within the framework of discipline rules.

Due to: 8th March 2017, Wednesday,

GOOD LUCK!!!

Bilkent University
2016-2017 Spring
IAED 342 Sustainable Design for Interiors

TASK I

A-Please rate the soundness of each example in Category A as a source domain for the defined design problem. (1-Poor, 2-Fair, 3-Average, 4-Good, 5- Excellent)				
Category A-1				
1	2	3	4	5
Category A-2				
1	2	3	4	5
Category A-3				
1	2	3	4	5
Category A-4				
1	2	3	4	5
Category A-5				
1	2	3	4	5
Category A-6				
1	2	3	4	5
Category A-7				
1	2	3	4	5
Category A-8				
1	2	3	4	5
Category A-9				
1	2	3	4	5
Category A-10				
1	2	3	4	5

B-Please rate the soundness of each example in Category B as a source domain for the defined design problem. (1-Poor, 2-Fair, 3-Average, 4-Good, 5- Excellent)				
Category B-1				
1	2	3	4	5
Category B-2				
1	2	3	4	5
Category B-3				
1	2	3	4	5
Category B-4				
1	2	3	4	5
Category B-5				

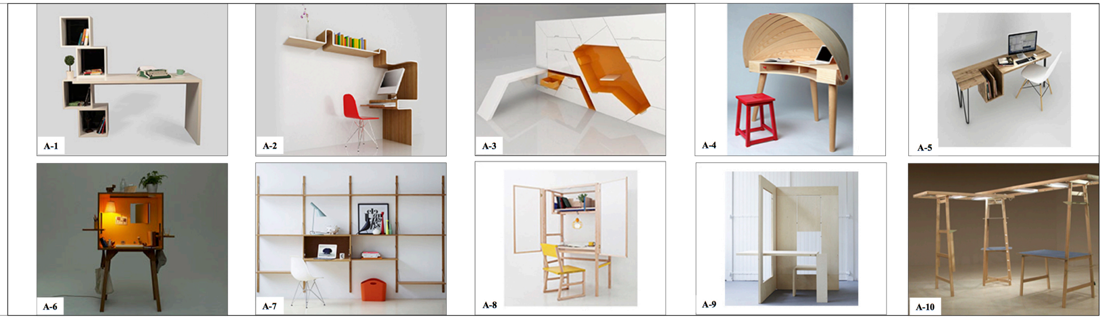
Category B-6				
1	2	3	4	5
Category B-7				
1	2	3	4	5
Category B-8				
1	2	3	4	5
Category B-9				
1	2	3	4	5
Category B-10				
1	2	3	4	5

C-Please rate the soundness of each example in Category C as a source domain for the defined design problem. (1-Poor, 2-Fair, 3-Average, 4-Good, 5- Excellent)				
Category C-1				
1	2	3	4	5
Category C-2				
1	2	3	4	5
Category C-3				
1	2	3	4	5
Category C-4				
1	2	3	4	5
Category C-5				
1	2	3	4	5
Category C-6				
1	2	3	4	5
Category C-7				
1	2	3	4	5
Category C-8				
1	2	3	4	5
Category C-9				
1	2	3	4	5
Category C-10				
1	2	3	4	5

TASK II

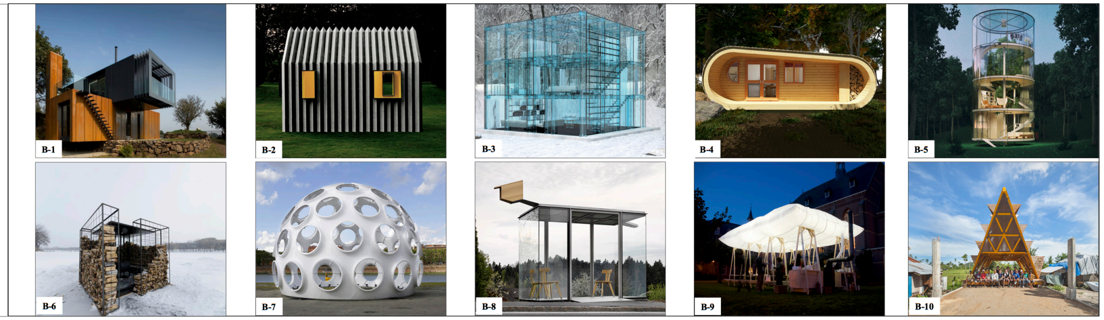
CATEGORY A

(NEAR)



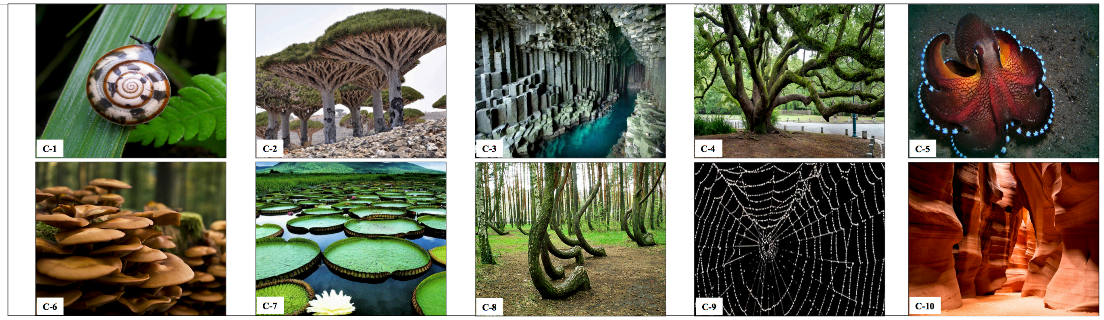
CATEGORY B

(MEDIUM)



CATEGORY C

(DISTANT)



TASK III

Please tick one of the relevant boxes to state your reason behind your selection of source domain.

- ☐ Aesthetics (Sense of form, art, or visual pleasing sensation that source example invokes)
- ☐ Experience (A similar project has been done or observed by the participant)
- ☐ Form (Shape, and other external visual appearance of the source example)
- ☐ Function (The way the source example will benefit or serve its users)
- ☐ Originality (Novelty and difference)
- ☐ Physical Property (Material, texture, or color of the source)
- ☐ Structure (The relationship among the elements of source example)
- ☐ Usability (Availability for all people regardless age, ability and size)

TASK IV

Please sketch your design solution for a workstation unit in plan, elevation and pespectives (at least two).

APPENDIX B

SETTING 2- CONSISTS OF TWO TASKS

01.03.2017

Research Homework

HW

A Sustainable Workstation Unit

The provision of sustainable built environments is not only matter of interior design, but also an essential material design and furnishing concern to enhance the quality of human life for safe, healthy and comfortable spaces. A high quality furniture design contributes positively to the wellbeing of the individual through the efficient use of site, energy, water, materials and resources of the general environment.

In this respect, your research homework is to design a sustainable workstation unit based on the IAED 342 course theoretical framework. A workstation unit is defined as an area that has the equipment needed for one person to do a particular job. The equipment in this problem includes a desk, a shelf and a lighting element. There are no dimensional considerations regarding the equipment. You are working individually. Your design process is composed of two tasks:

Task1- Choose ONLY ONE design criterion, which is the most appropriate for your design.

Task 2- Sketch your design solution for a sustainable workstation unit in plan, elevation and perspectives (at least two) in the given A3 sheet.

Your DESIGN must be your own analyses, so should not be copied from any Internet source. Unauthorized aid or assistance on any form of academic work (Cheating), copying another work and adopting as same as one's own work (Plagiarism) and untruth statements are not allowed (Falsification) and treated within the framework of discipline rules.

Due to: 10th March 2017, Friday,

GOOD LUCK!!!

Bilkent University
2016-2017 Spring
IAED 342 Sustainable Design for Interiors

TASK I

Choose only one design criterion, which is the most appropriate for your design.

- ☐ Aesthetics (Sense of form, art, or visual pleasing sensation that source example invokes)
- ☐ Experience (A similar project has been done or observed by the participant)
- ☐ Form (Shape, and other external visual appearance of the source example)
- ☐ Function (The way the source example will benefit or serve its users)
- ☐ Originality (Novelty and difference)
- ☐ Physical Property (Material, texture, or color of the source)
- ☐ Structure (The relationship among the elements of source example)
- ☐ Usability (Availability for all people regardless age, ability and size)

TASK II

Please sketch your design solution for a workstation unit in plan, elevation and pespectives (at least two).

APPENDIX C

MENTAL EFFORT QUESTIONNAIRE

Cognitive Load Mental Effort Questionnaire (* adapted from Paas, 1992)

1. Sustainable problem solving process for a workstation unit requires								
1 Very very low effort	2	3	4	5 Neither low or high mental effort	6	7	8	9 Very very high mental effort
2. To understand the requirements of the workstation unit I invested								
1 Very very low effort	2	3	4	5 Neither low or high mental effort	6	7	8	9 Very very high mental effort
3. To analyze resources/the source domains of the workstation unit I invested								
1 Very very low effort	2	3	4	5 Neither low or high mental effort	6	7	8	9 Very very high mental effort
4. To synthesize resources/the source domains of the workstation unit I invested								
1 Very very low effort	2	3	4	5 Neither low or high mental effort	6	7	8	9 Very very high mental effort
5. To achieve a sustainable design solution for the workstation unit I invested								
1 Very very low effort	2	3	4	5 Neither low or high mental effort	6	7	8	9 Very very high mental effort

* Paas, F. G. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology, 84*(4), 429-434.

APPENDIX D

CREATIVITY ASSESSMENT SURVEY

Name: ____________________ Gender: F ______ M ______

CREATIVITY ASSESSMENT SURVEY (* taken from Demirkan & Afacan, 2012)

	1	2	3	4	5	
Integrated						Disjointed
Coherent						Jumbled
Detailed						Vague
Refined						Undeveloped
Deliberate						Accidental
Polished						Rough
Balanced						Unbalanced
Significant						Insignificant
Adequate						Inadequate
Sensible						Unrealistic
Different						Typical
Unconventional						Conventional
Unknown						Familiar
Infrequent						Frequent
Rare						Standard
Extraordinary						Regular
Limited						Unlimited
Evolving						Not evolving
Exciting						Dull
Zippy (Canlı)						Bland (Donuk)
Fresh						Overused
Eccentric						Conventional
New						Old
Novel						Predictable

	1	2	3	4	5	
Unusual						Usual
Unique						Ordinary
Original						Commonplace
Pleasant						Unpleasant
Good						Bad
Delighted (Keyifli)						Horrified (Dehsetengiz
Appealed (Cazip)						Revolted (İğrenç)

* Demirkan, H, & Afacan, Y. (2012). Assessing creativity in design education: Analysis of creativity factors in the first-year design studio. *Design Studies, 33*(3), 262-278.

APPENDIX E

SUSTAINABILITY EVALUATION FORM

SETTING I (Sustainable problem solving using analogical reasoning)

SEC001

Student Name/Surname:

	EVALUATION CRITERIA (*adapted from Moxon, 2012; Winchip, 2007)	GRADING	TOTAL
1	Application of new technologies/ eco technologies	10	
2	A future focused strategy (a holistic approach)	10	
3	Use of recycled materials	10	
4	Use of non-toxic materials	10	
5	Use of locally sourced materials	10	
6	Use of energy-efficient system	10	
7	Provide space to promote healthy working	10	
8	Durability	10	
9	Flexible design/modularity	10	
10	Simple Design (Avoidance of over-complicated design)	10	
			100

Comments:

* Moxon, S. (2012). *Sustainability for Interiors*. London: Laurence King Publishing.

Winchip, S. M. (2007). *Sustainable design for interior environments*. New York: Fairchild.

SETTING II (Sustainable problem solving using traditional design methods)

SEC002

Student Name/Surname:

	EVALUATION CRITERIA (*adapted from Moxon, 2012; Winchip, 2007)	GRADING	TOTAL
1	Application of new technologies/ eco technologies	10	
2	A future focused strategy (a holistic approach)	10	
3	Use of recycled materials	10	
4	Use of non-toxic materials	10	
5	Use of locally sourced materials	10	
6	Use of energy-efficient system	10	
7	Provide space to promote healthy working	10	
8	Durability	10	
9	Flexible design/modularity	10	
10	Simple Design (Avoidance of over-complicated design)	10	
			100

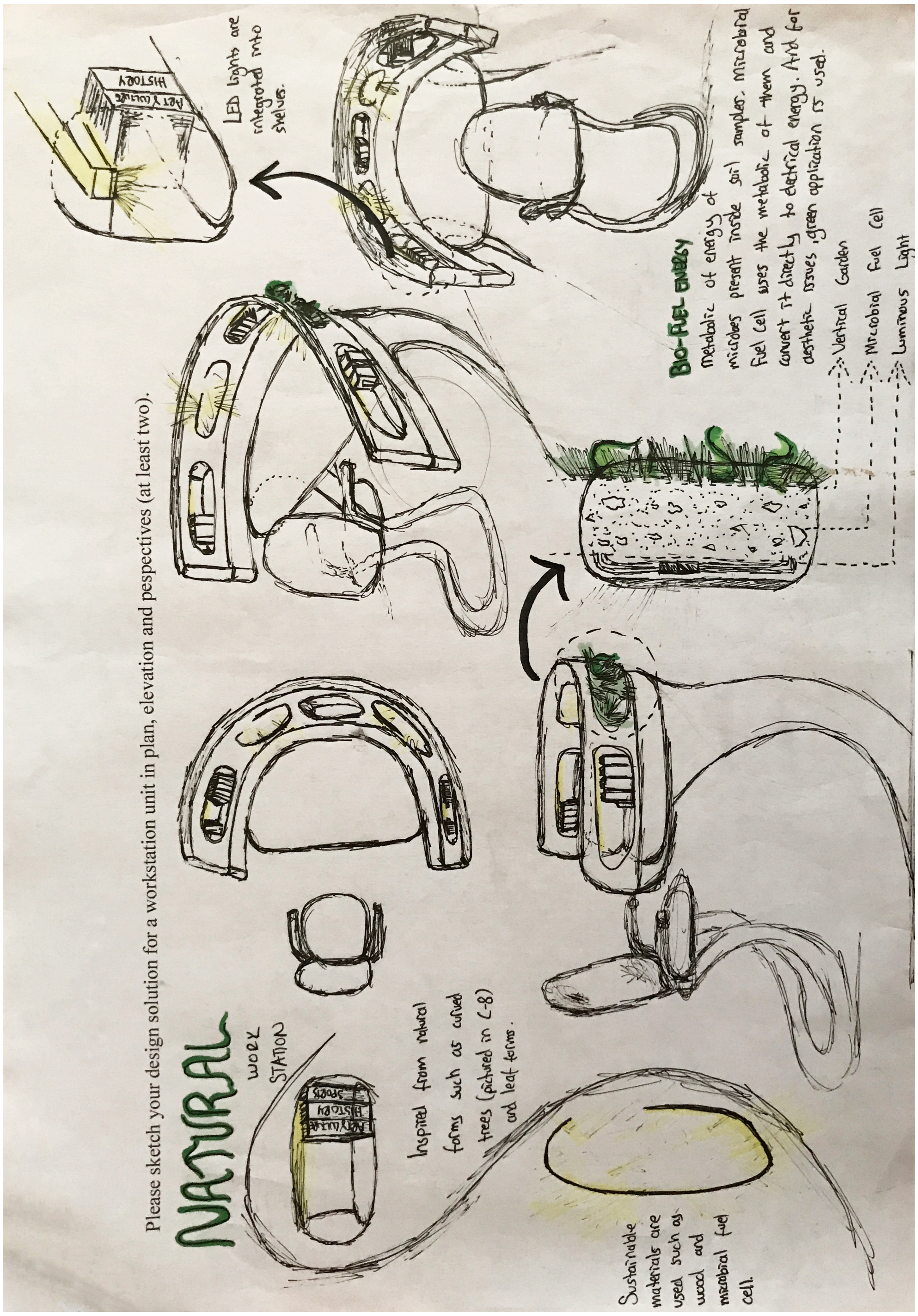
Comments:

* Moxon, S. (2012). *Sustainability for Interiors*. London: Laurence King Publishing.

Winchip, S. M. (2007). *Sustainable design for interior environments*. New York: Fairchild.

APPENDIX F

DESIGN OF THE MOST SUCCESSFUL STUDENT IN SETTING 1



APPENDIX G

DESIGN OF THE MOST SUCCESSFUL STUDENT IN SETTING 2