

FOSTERING CREATIVE COGNITION IN DESIGN EDUCATION: A COMPARATIVE ANALYSIS OF ALGORITHMIC AND HEURISTIC EDUCATIONAL METHODS IN BASIC DESIGN EDUCATION

Zeynep Çiğdem UYSAL ÜREY*

Received: 29.08.2020; Final Text: 08.06.2021

Keywords: Design cognition; creativity; algorithmic method; heuristic method; basic design education.

INTRODUCTION

Design cognition studies have discovered several aspects of the design process so far, such as the characteristics of creative design (Eastman, 1969; 2001; Akin, 2001; Cross, 2001), cognitive processes and stages in the realization of the design process (Lawson, 1980; Cross, 2001; Wallas, 1926; Jansson et al., 1992), and the techniques that define the levels of creativity in creative design (Welling, 2007; Cross, 2001; Oxman, 2004). However, the impact of educational methods in the development of creativity and creative problem-solving ability in design has been examined by a limited number of studies (De Leeuw, 1983; Renki, Hilbert and Schworm, 2009; Ruscio and Amabile, 1999; Yang et al., 2016). Furthermore, the impact of algorithmic and heuristic educational methods in basic design education has not been studied as of yet.

This research aims to study the impact of algorithmic and heuristic educational methods in basic design education in an attempt to see their effects on the development of the creative cognition of students. In order to investigate this impact, both a systematic theoretical review and a qualitative analysis have been conducted in this research. The systematic theoretical review has been conducted both in the studies of design cognition and creativity and also in the studies of design education. Regarding the subject of design cognition and creativity; the studies on the characteristics of creative cognition in design, the cognitive processes and phases in the emergence of novelty in design, and the characteristics of algorithmic and heuristic problem-solving in creative design have been examined. Regarding the subject of design education; the cognitive constructivist, social constructivist and experiential learning theories were examined in relation to design cognition and education; and the characteristics of architectural design and basic design education were investigated in relation to algorithmic and heuristic educational methods.

* Department of Architecture, Faculty of Architecture, Çankaya University, Ankara, TURKEY.

The qualitative analysis has been carried out in the first-year basic design studio of the architecture department, with an attempt of making a comparison between the impacts of algorithmic and heuristic educational methods, through a creativity assessment of the projects of the two consecutive semesters. The analysis was made respectively on the pre-final projects of Fall 2016-2017 semester, which was carried out by means of algorithmic educational method, and Fall 2017-2018 semester, which was carried out in line with heuristic educational method. The algorithmic and heuristic methods were implemented both in the preparation of design assignments and also in the realization of the educational approach. In algorithmic education, the design assignments were more descriptive in terms of the types of design elements to be used, their characteristics, numbers, and methods of use, as well as in terms of the types and characteristics of the materials. In heuristic education, a more flexible attitude had been adopted and the design assignments incorporated more freedom both in the types of design elements to be used, their characteristics, numbers, and methods of use, and also in terms of the types and characteristics of the materials. The educational approach was also more prescriptive in the algorithmic education, guiding the student to the solution by means of explicitly delineated procedures and demanding from the student the exact formal/geometrical rules that were used in the development of design. The heuristic educational approach, on the other hand, gave more freedom and initiative to the student and took a less structured approach both in the guidance of the student and the demanded responses from him/her.

The analysis was designed as to have two stages. In the first stage, an evaluation was made by means of a creativity assessment model developed by the author, which was based on the evaluation of creativity over products. The analysis attempted to observe the creativity levels of the projects for the selected assignment for each semester. The assessment model was developed as based on Sternberg and Lubart's creativity definition for products, which defined creativity as "the ability to produce work that is both novel and appropriate" (Sternberg and Lubart, 1999). The two criteria in Sternberg and Lubart's creativity definition for products, which are novelty and appropriateness, become the two main parameters of this analysis. The novelty and appropriateness indices were further detailed and expanded to include the project evaluation criteria of the studio (**Tables 2 and 3**). The projects were analyzed according to these parameters by means of a five-point scale. The aim in this analysis was to observe which semester had higher points in terms of their novelty scales. In the second stage of the analysis, the assignment grades of students were analyzed for each semester to compare the number of outstanding projects, the number of average projects, the number of unsuccessful projects, and the mean value of grades for each semester, with an attempt of forming an insight about the success of each semester in terms of their levels of creativity and design ability. All in all, both by the theoretical review and the qualitative analysis, the research tried to evaluate the impact of algorithmic and heuristic educational methods in basic design education in an attempt to see their effects on the development of the creative cognition of students.

ALGORITHMIC AND HEURISTIC PROBLEM-SOLVING STRATEGIES IN DESIGN COGNITION AND CREATIVITY

Design problems are examined within the scope of creativity and problem-solving area in cognitive psychology literature. Defined as the activity of creating a product that is configured to perform a specific function, design describes the conscious effort of creating something that is both functional and aesthetically pleasing (Jansson et al., 1992, 265). Comprising as such, mainly the creative endeavors of planning, inventing, or making, design is found to have its unique ways of thinking and realizing things (Cross, 2006, 1). These specifics about design are examined by the area of design cognition, which studies "human information processing in design", by using different theoretical and empirical paradigms (Eastman, 2001, 147).

One crucial aspect both for design and problem solving appears to be creativity. Creativity is defined as "the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (Sternberg and Lubart, 1999, 3). As a property of thinking, it is defined either as the ability of producing lots of new ideas or the capacity to make new associations between the already existing ones (Sternberg and Lubart, 1999). Consisting both of these aspects, creativity can be defined as the "coordination of things into new structures", which are regarded as "unusual or new to the mind" and are "appropriate to the characteristics of a desired solution" (Warr and O'Neil, 2005, 118-27).

The emergence of novelty during the creativity process is found significant in terms of the formation of the creative response. For this reason, many studies examined the cognitive processes that take place in creativity and creative design in order to understand how the novel response is formed (Wallas, 1926; Lawson, 1980; Finke, Ward and Smith, 1992; Jansson, Condoor and Brock, 1992). Proposing one of the first models of the creative process, Wallas (1926, 82-5) argued that creativity took place in five stages, which were preparation, incubation, intimation, illumination, and verification. Among these, he portrayed the stage of illumination, which occurs "when a promising idea suddenly becomes consciously available", as the stage where novelty arises (Wallas, 1926). Finke, Ward, and Smith (1992), on the other hand, proposed the Geneplore Model, suggesting that there are exploratory and generative stages taking place in the creative act, where several cognitive processes, such as insights (forming unconscious connections through creative leaps), extending from familiar concepts, activating prior knowledge, conceptual combination, and creative imagery, were used in the generation of the creative response. The process of insight in this model is very similar to Wallas' illumination stage, in terms of the emergence of novelty.

In order to explain the degree of novelty appearing in creative design, several studies delineated the role of different cognitive processes that are used during the creative process (Welling, 2007; Cross, 2006; Yilmaz et al., 2011). Welling model lists these processes as application, analogy, combination, and abstraction, and suggests that the amount of novelty in creative works increases from the application pole towards the abstraction pole (Welling, 2007, 163). Cross' model, on the other hand, includes the processes of combination, mutation, analogy, designing by the first principles, and emergence, and like Welling, suggests that the amount of novelty increases towards the pole of emergence (Cross, 2006, 50).

As these models demonstrate, creativity includes ordinary cognitive processes, which are applied to knowledge already stored in memory, producing novel results (Sternberg and Lubart, 1999). As Cross (2006) argues, the novelty of these results occurs by means of a creative leap, which is taken across the gap between functional design requirements and formal structure of the new product. This creative leap is defined as a sudden surge of a completely new perspective on the existing situation, and its breadth is thought to be determined by how the cognitive processes are employed (Cross, 2006, 44). The extent of the use of cognitive processes and the degree of novelty of the target problem is thought to make some creative contributions have greater amounts of novelty than others.

Although these studies have discovered many aspects of creativity and the emergence of novelty in design, the essence and characteristics of the creative act still remain to be known (Welling, 2007, 163). The same is also true for the assessment of creativity. There are some creativity assessment models; such as the Torrence Test of Creative Thinking (TTCT) that makes a process-based assessment of divergent thinking; but their reliability is questioned today. It is accepted that there is still no standardized measurement technique for creativity, neither for persons nor products (Sternberg and Lubart, 1999; Lawson, 1994). One thing that is agreed upon though is that creativity cannot be assessed in isolation (Csikszentmihalyi, 1994), as it is the product of many diverse dimensions, such as the person, process, product and the press (environment), which are defined as the 4P's of creativity by Rhodes (1961). Creativity assessment can be made as based on these four different dimensions.

In cognitive psychology literature, creativity is studied in relation to problem-solving. Problem-solving is defined as the systematic search we employ when we need to overcome obstacles to answer a question or to achieve a goal (Matlin, 2014). As literature portrays, a problem exists when our current state is different from our desired or goal state. In problem-solving process, we gather information we need and transform that information to reach an appropriate answer. Every problem is thought to have four main components: initial state, operators (strategies we apply), obstacles (limitations we experience), and goal state (what we want to accomplish). The totality of these four steps is called the problem space (Matlin, 2014, 371).

Since 1950s, several problem-solving models were developed by cognitive psychologists and computer scientists (Bunning et al., 2011, 162). Sternberg's highly accepted problem-solving model proposes a problem-solving cycle that includes seven steps, which are: problem identification, problem definition, strategy formulation, organization of information, allocation of resources, monitoring problem solving, and evaluation (Sternberg, 2007, 393). Of these steps, problem identification, or problem finding, is portrayed as the most important step for creative endeavors, as the novelty of the product depends on how the creator identifies and defines the problem himself (Sternberg, 2007).

In the literature, problems have been classified as well-defined problems and ill-defined problems. In well-defined problems, the initial problem state, the operators to be used on that problem state, and the goals to be reached are identified. These problems have only one correct solution, a guaranteed method for finding that solution, and clear solution paths (e.g., mathematical problems) (Eastman, 1969, 669). The problems in physical sciences and engineering are considered to be well-defined problems.

In ill-defined problems, on the other hand, the initial problem state, the operators (strategies) to be used on that problem state, the formal language for depicting the problem space, and the goals to be reached are imprecisely defined. The problem solver should define these himself. These problems have more than one acceptable solution, no universally agreed-on strategy for reaching that solution, and they lack clear paths to their solutions. The solution of ill-defined problems necessitates insight, which is described as the sudden understanding of a problem or finding a strategy, by forming new connections between prior and newly attained knowledge or by seeing the problem from a new perspective (Akin, 2001). Design problems, in general, are considered as ill-defined problems (Cross, 2001; Eastman, 1969).

For ill-defined design problems, there are endless possibilities for defining the problem, selecting the operations and determining the end product (the goal). It must be the designer who has to frame and set the boundaries to this vast problem space (Schön, 1988). In order to frame this problem space, the designer recalls his prior knowledge and the strategies he has used before. For this reason, the amount of domain-specific knowledge that the designer has (declarative knowledge), and the amount of strategies (procedural knowledge) he acquired by solving previous problems become important for the solution of design problems (Simon, 1973; Bruning et al., 2004). The comparative studies on expert and novice designers show that this difference in the amount of declarative and procedural knowledge exists as the main reason that differentiates the experts from novices in their ability and efficiency in design problem solving (Oxman, 2004). With larger chunks of domain knowledge and design strategies, experts are faster in developing solutions and are able to produce more solution alternatives to design problems (Akin, 2001). As Lawson (1980) suggests, this is the reason that the education of designers/architects is loaded with precedent studies and design practices taking place by guided discovery at studios settings.

In relation to problem solving, the literature lists two main problem-solving strategies that could be used both for well-defined and ill-defined problems, which are the algorithmic and the heuristic problem-solving strategies (Brunning et al., 2004; Sternberg, 2007; Matlin, 2014). Algorithms are defined as rule-based strategies to solve problems. In algorithmic problem solving, the problem solver follows certain steps and/or rules towards a specified goal, in a straightforward manner (Ruscio and Amabile, 1999). In theory, algorithms are guaranteed to produce a solution if they are correctly executed (i.e., finding the solution of a mathematical problem by an accepted formula, or following a recipe for cooking a meal) (Sternberg, 2007). An algorithm is more specifically defined as a group of progressive actions, a set of steps, rules or instructions that are executed to find the solution of a problem or to reach to a result (Terzidis, 2006; Sternberg, 2007; Sorguc, 2015). As Terzidis (2006, 65) outlines, it is "a procedure for addressing a problem in a finite number of steps using logical if-then-else operations". An algorithm therefore is an operation of human mind that follows a rule-based procedural logic and it is a mode of rational thinking which is distinguished as being "precise, definite and logical" (Terzidis, 2006, 16). It contains finite, intelligible and rational steps that may or may not include computation (Terzidis, 2006, 15) (1).

In cognitive psychology literature, algorithms are seen in contrast to heuristics. Heuristics (rules of thumb) are defined as the exploratory,

1. Algorithms are also the set of instructions written/given by a human to a computer to perform a specific task. After the invention of computers, algorithms are used as a language to communicate with computer's reasoning, simulating human cognitive processes to perform several tasks (Terzidis, 2006; Chan, 2015). In the scope of this paper however, algorithm will be taken as a human cognitive ability and will be examined both as a problem-solving strategy and as an educational method, as being delineated in the cognitive psychology literature.

informal and intuitional problem-solving strategies that utilize educated guesswork rather than predefined rules (Sternberg, 2007). They are described as the mental shortcuts that are formed by means of prior knowledge and experience, acting as effective and time-saving tools in the process of problem-solving (Sternberg, 2007). Associated with intuition, creativity, and insight (Simon and Newell, 1957, 5), they are found to be faster than algorithms, but they are also known not to always guarantee a solution or sustain the accuracy provided by an algorithm. As Renki et al. (2009, 69) state, in a problem-solving process, if there are distinct solution steps, it is considered algorithmic, if not, it is heuristic. Heuristics are generally used when the problem space is too big, the time is limited, and the analogy to a previously solved problem is too obvious (Matlin, 2014). Therefore, as Simon and Newell (1957, 5) state, we use mostly heuristics (mental shortcuts) for solving ill-defined problems, as we have a limited short-term memory, which can process only a few number of operations/information at one time (Simon and Newell, 1957; Sternberg, 2007).

The literature lists the commonly used heuristics as trial and error (generate and test), means and ends analysis, working forward, working backward, and analogy (Sternberg, 2007; Matlin, 2014). In trial and error method, the problem solver is faced with an unfamiliar problem, where he first evaluates his options by random trying, only to switch to a more efficient method with the help of the preliminary information he obtained through trial. In means and ends analysis, the problem solver tries to reduce the distance to the goal by following a sequence of steps, which begins by the definition of the goal state and follows by breaking down the problem into smaller sub-problems, and finishing and evaluating each step before going to the next. In working forward method, the problem solver tries to solve the problem from the start to the end, and in contrary to that, in working backward method, the problem solver starts at the end of the problem and works his way backwards to the beginning (Sternberg, 2007). In analogy, the problem solver compares the newly confronted problems with previously experienced similar problems, and employs the strategies used in them to reach to a new solution (Matlin, 2014). Analogy holds a key importance as a heuristic in creative cognition and exists as a vital process of human mind whereby novel problems are solved in science, arts, and design (Gentner et al., 2001).

The literature on different research areas display different approaches towards heuristic and algorithmic problem-solving in design. Design cognition literature points out the significant role that heuristics play in design creativity and problem-solving (Eastman, 1969, 2001; Yilmaz et al., 2011; Yang et al., 2016); and state that because of their huge problem spaces and need of unexpected solutions, ill-defined design problems could not be solved by a defined set of operators, fixed number of steps or algorithms (Chan, 2015; Casakin, 2005; Suwa et al., 1999). Pointing out that designers generally use visual reasoning and pictorial-spatial representations - instead of numerical ones - to generate forms (Casakin, 2005), the studies suggest that design reasoning could not be seen as "totally a formal logical operation with specific algorithms in place, but a certain way of informal reasoning" that guides the process of design (Chan, 2015, 52). For this reason, they claim that designers essentially use heuristics as a cognitive strategy for developing the problem-solution frame and for executing higher level operations in the problem-solving process (Chan, 2015, 43-4).

2. In the scope of this paper, algorithmic approach will be referred to as a rule-based cognitive problem-solving strategy and as an educational method, as explained by cognitive psychology literature, and will not be referred to as computational/digital design, as referred by computational design literature.

Acknowledging that most of the designers practice in an ad-hoc and unsystematic way (Cross, 2001), design cognition studies assert that heuristic problem-solving methods, such as trial and error, means and ends analysis, or analogy are used extensively by designers to come up with novel solutions. These heuristics are considered to be developed in time by designers by means of acquiring domain knowledge and solving design problems through years of practice (Chan, 2015). As Yang et al. (2016) shows, the retrieved domain knowledge, in the form of types, precedents or prototypes, act as key heuristics in design, getting operated by analogy in the formation of insights to design problems. A suitable heuristic as such is thought to frame the vast problem spaces of ill-defined design problems, increasing the rate of problem-solving significantly (Yang et al., 2016). Therefore, although difficult to encapsulate, heuristic problem-solving methods are considered indispensable for the process of design.

Computational design literature, on the other hand, points out the merits of algorithmic and computational thinking in design and creativity, and draws attention to the possibilities that could be brought about by the use of algorithms in design, either by means of an algorithmic thinking approach or by computational design using digital technologies. In this literature, algorithmic design specifically refers to design making by means of writing the codes of a computer software that creates the space and form (Terzidis, 2006); and very close to it, parametric design refers to design making by using parametric modelling programs, where the designer alters the parameters to produce design alternatives (Terzidis, 2005; Globa, 2015) (2). These studies assert that by means of altering the algorithms (codes) or changing the parameters within the digital design process, computational design systems can provide architects with substantial opportunities for formal explorations, multiple and unpredicted formal outcomes, the means to deal with relational/formal complexity and ambiguity, and the production of complex design solutions and unorthodox/non-standard geometries (Terzidis, 2006; Mennan, 2008; Ucar, 2006; Globa, 2015).

They point out that since these systems can calculate, represent and manufacture these formal complexities at the same time, they set the designer free to create complex, dynamic and non-standard geometries, to explore different space definitions, and save him from being limited to the use of orthogonal geometries. As such, they increase the intuitional/creative capacity of the designer by expanding his limits (Mennan, 2008; Ucar, 2006). As Terzidis (2006, 16) notes, although algorithmic design maybe seen as an overly rational process in terms of its procedural syntax, it is able to generate products that can be quite unpredictable and ambiguous, as it initiates an open-ended, unpredictable formal design process. Therefore, these studies suggest that the use of algorithms in design can result in unpredictability and unpredicted complexity, which increases the creative potential of design solutions and broadens how designers can think afterwards (Terzidis, 2006; Mennan, 2008).

All in all, the studies in these two areas of research show that both the heuristic and the algorithmic thinking strategies have their own potentials for design thinking, which can play a significant role in the emergence of creativity and formation of novel design solutions.

3. Since the beginning of 1900's several learning theories and models have been developed under the guidance of different theoretical perspectives of behaviorism, cognitivism, constructivism, and humanism, such as Piaget's Theory of Cognitive Development (1936), Vygotsky's Theory of Learning (1934), Bloom's Domains of Learning Theory (1956), Bruner's Cognitive Learning Theory (1966), Maslow's Hierarchy of Needs Theory (1962), Gardner's Multiple Intelligences Theory (1983), or Kolb's Experiential Learning Theory (1984), which point out different characteristics of the learning process that could be developed by educators (Stevens-Fullbrook, 2020).

4. Learning style is described as the specific way that the individual learns something, which he is naturally inclined to and uses whenever he learns something (Cassidy, 2004; Demirbas and Demirkhan, 2003). Being specific to individuals, learning styles are found to be determinant in how learning takes place (Cassidy, 2004). Several learning style models have been developed since 1960's, such as Witkin's Field dependence-independence model (1962), Kagan's impulsivity-reflexivity model (1965) or Kolb's Experiential Learning Model (1984) (Cassidy, 2004). Kolb's model defines four learning styles, which are "accommodating" (combining active experimentation and concrete experience), "diverging" (combining concrete experience and reflective observation), "assimilating" (combining reflective observation and abstract conceptualization), or "converging" (combining abstract conceptualization and active experimentation) (Demirbas and Demirkhan, 2003). As Demirbas and Demirkhan (2003) study states, design education activates all these learning styles in Kolb's model through the different phases of its educational program (Demirbas and Demirkhan, 2003, 452).

ALGORITHMIC AND HEURISTIC EDUCATIONAL METHODS IN DESIGN EDUCATION

In the literature, algorithmic and heuristic approaches are discussed not only as strategies of problem-solving and design thinking but also as educational methods that affect the learning and problem-solving abilities of students. In order to understand how these educational methods might impact learning and problem-solving in design, it would be necessary first to understand how design learning and education take place by means of examining learning theories, and especially cognitive constructivist, social constructivist and experiential learning theories, which have become significant for the understanding of design learning.

Since the early 20th century, it became widely acknowledged that our cognitive development occurs by means of our own knowledge construction in relation to what we already know, and it takes place within a social context by means of our interactions with other (knowledgeable) people (Bruning et al., 2004, 193) (3). Forming the theoretical perspectives of cognitive constructionism and social constructivism, these views mainly suggest that learners construct their own knowledge, and their social interactions become very important in this construction. In constructivist learning environments as such, students are encouraged to take a more active role in learning, and teachers are not just seen as information givers but as coaches or facilitators that put up a dialog with the students (Bruning et al., 2004, 195).

These perspectives brought up new learning models such as Rogoff's guided participation (or apprenticeship in thinking) model or Schön's reflection in action model. They both suggest that "cognitive growth is best fostered in a social environment in which students are active participants and where they are helped by teachers to reflect on their learning" (Bruning et al., 2004, 203). Rogoff's guided participation model states that cognitive development takes place through guided activity, when novices (or the apprentices in thinking), are guided by experts in problem-solving activity (Rogoff, 1990; Bruning et al., 2004). Schön's (1985) reflection in action model, on the other hand, underlines the necessity of guided discovery for learning and argues that students cannot be taught, but they can only learn themselves by doing, under the guidance of teachers. Schön (1985) states that ideal learning environments are practice situations where students learn by doing and take feedback from teachers.

Similar to Schön and Rogoff, the experiential learning theory of David Kolb (1984) argues that theoretical declarative knowledge and practical procedural knowledge can only be integrated by learning in action, through experience (Kolb, 1984; Salama, 2015). For Kolb, experience is critical in knowledge construction, and learning occurs through the transformation of experience (Bruning et al., 2004). Defining a learning cycle that takes place through four consecutive processes, which are experiencing, reflecting (analyzing what is experienced), formation of abstract concepts, and acting (testing those concepts by experimentation), Kolb states that any learner follows through all these steps, although in different degrees in relation to their learning styles (4) (Kolb, 1984; Salama, 2015; Demirbas and Demirkhan, 2003).

The processes of self-guided discovery, active participation and experiential learning, suggested all by Rogoff, Schön, and Kolb, are especially relevant for design disciplines, where students learn by doing under the guidance

of an experienced tutor. Design studios act as reflective classrooms, where the educator tries to develop the declarative and procedural knowledge of students by means of guiding them during the design of their projects. Being at the core of architectural education, design studio is described by Schön (1983) as the ideal learning environment where learning by doing and guided self-discovery takes place. By means of a project-based education, students experience hands-on problem-solving in design studio, under the guidance of their instructors (Schön, 1985; Oxman, 2004; Akin, 2001). In this process, students learn by themselves and are only guided by their instructors while they do so, through the dialogue initiated by critique sessions over the design problems (Schön, 1985). All this learning by doing itself acts as a teacher.

In design studio, the products produced by the students enable the studio session to take place, discussions exist only if a product is present, and the quality of the product determines the quality of the discussion (Green and Bonollo, 2003). Therefore, in studio setting, student is not the passive learner and the teacher is not the active provider of knowledge, but there is an interactive collaboration between them. The educator guides the self-learning process of students, and the students act as self-directed active learners (Bruning et al., 2004, 204). Developing an autonomous and active thinking approach as such, students demand information themselves for developing novel solutions to design problems given at the studio (Salama, 2015; Teymur, 1992). With these characteristics, design studio exists as the unique element of architectural education, where the creative problem-solving ability of students are developed by means of experiential learning and guided self-discovery.

In many architectural schools, the first design studio of architectural education is the course of basic design. Having its roots both at the Bauhaus of Weimar and VKhUTEMAS of Moscow in 1920s (Özkar, 2004; Salama, 2015), basic design course depends essentially on experiential learning, where the creativity and design ability of students are developed through abstract design problems (Ozkar, 2004). The main aim of the course is defined as to teach the students how to form conscious relationships between forms. Abstract forms are seen as the essential tools in this process to reveal and focus on these relationships more clearly (Özkar, 2004). With their detachment from familiar data, abstract forms disengage thought from standard mental patterns and allow for experimentation about form relationships (Özkar, 2004, 119). The formal relationships and visual possibilities are explored in the course through hands-on experimentation with materials. In this free experimental process, the sensory experiences of the student are found as indispensable, enabling the student to find his/her own methods in approaching the problem and learning by doing without pre-defined formulas (Özkar, 2004; Teymur and Aytac Dural, 1998). As Ozkar (2004) states, the reasoning process that is developed as such emerges within the circumstances of uncertainty, diversity, and sensory-intuitive hands-on experimentation with materials. These circumstances, and especially uncertainty, are defined as the key aspects for the development of creativity in basic design education (Ozkar, 2004).

As Ozkar (2004) states, the roots of this hands-on experimentation in basic design can be traced back to the experiential, hands-on learning theories of 19th-century child educators Johann Pestalozzi and Friedrich Froebel. Johannes Itzen, who was the creator of Vorkurs (the basic design course at

Bauhaus), was a former kindergarten teacher, educated by Pestalozzi and Froebel's theories (Özkar, 2004). Itzen celebrated this personal, sensory, hands-on learning by calling it 'intuitive finding' and used this method to reveal the individual's unique characteristics and enable him to express himself (Itten, 1975). As Ozkar (2004) states, Itten believed that creativity would emerge this way as the personal heuristic act of the individual. Although this educational approach later changed towards a more rational and functionalist one when Itzen left and Moholy-Nagy took over (Özkar, 2004), Itzen's original aims still resound in today's basic design courses. Being still at the foundational core of basic design course, the sensory and experiential learning approach tries to provide a less certain and less restrictive environment for the development of creativity in first-year studio (Özkar, 2004).

The literature shows that the self-guided and experiential learning processes and the creative problem-solving attitudes of students in design are affected differently by different educational methods. The studies bring forward especially two different educational methods that prove to have different impacts on the learning and creative problem-solving abilities of students, which are the algorithmic and the heuristic educational methods. Algorithmic educational method is described as a method of education where all the necessary steps and operations to be taken in the course of learning and in the solution of the problem are explained and prescribed to the student (Leeuw, 1983). In this method, the instructor follows a prescriptive approach and the student is step by step guided to the solution. Heuristic educational method, on the other hand, is described as a method of education where finding of the necessary steps and operations of learning a subject or solving a problem is left to the student (Leeuw, 1983, 2). While heuristic education leaves more initiative to the student, expecting his/her inventiveness, algorithmic education directs the student through clearly outlined procedures. Likewise, while algorithmic education gives more structure to the educational medium, heuristic method creates a less structured medium, which affects the problem solving and learning abilities of students differently (Leeuw, 1983).

The literature includes different approaches towards the use of heuristic and algorithmic educational methods in the areas of problem solving and creativity. There are studies that assert that heuristic educational method supports the exploratory, active and creative aspects of the student, while algorithmic educational method impedes those (Ruscio and Amabile, 1999; Leeuw, 1983; Bruner, 1960; Casakin, 2005; Chan, 2015). In their study, comparing the impact of algorithmic and heuristic education on creative problem solving, Ruscio and Amabile (1999) state that students who were instructed heuristically showed much more exploratory behavior and were able to generate more novel solutions than students who were instructed algorithmically. The students in algorithmic education showed more confidence and speed in applying what they were shown (by replicating a standard); however, they were less exploratory than the students in the heuristic group. The students who were in heuristic education, on the other hand, were able to apply their knowledge to a wider set of problems in comparison to the students in the algorithmic group (Ruscio and Amabile, 1999). Based on these results, Ruscio and Amabile (1999) assert that an education with a flexible and broad heuristic approach would be more successful than a rigid and specific algorithmic approach in terms of enabling students to solve not only familiar but also novel problems (Ruscio and Amabile, 1999).

Cognitive studies assert that the feeling of autonomy, freedom, and uncertainty feeds the creative performance and have to be present to a degree for acting creatively in the face of ill-defined problems (Orhon, 2014; Wilson and Zamberlan, 2017). As these problems necessitate finding the solution steps by oneself, being able to be self-directed appears to be a must. The studies state that creativity is likely to occur more in less extrinsic constraint conditions as the external constraints in a design problem limit imagination and design creativity (Chan, 2015, 37). On this basis, studies claim that as the heuristic educational method decreases the external constraints to a degree and enables the students to deal with uncertainties of design process in a self-directed, experiential manner, it is likely to support their creative potential (Wilson and Zamberlan, 2017). Moreover, they claim that as the heuristic education enables the student to choose his behavior without pressure, it supports his intrinsic motivation, which, in turn, increases his work engagement, persistence, and creativity (Bruning et al., 2004; Ruscio and Amabile, 1999; Csikszentmihalyi, 1994).

Cognitive studies further claim that heuristic education activates mostly the intuitive, imaginative, and spatial form of thinking, while algorithmic education activates the analytical, sequential, and linear form of thinking (Orhon, 2014; Bruner, 1960; Salama, 2015). Bruner (1960) states that since intuition thinking is the building block of creativity, it should not be undermined by the imposition of extreme discipline and control through an analytical and algorithmic education. Imposing an overly algorithmic method by bringing a forced rationalization to this process would inhibit creativity and eliminate the unique features of its education (Schön, 1985; Cross, 2006). On this basis, the studies assert that for educating students to have creative thinking skills, the heuristic-intuitive thinking ability should be fostered and not suppressed by an analytical-algorithmic education at the extreme (Orhon, 2014; Bruner, 1960). The educators should find a balance between a prescriptive approach that restricts students' creativity and a totally free approach that leaves them unguided (Wilson and Zamberlan, 2017). All in all, they claim that by supporting freedom, self-directedness, uncertainty, exploration and intrinsic motivation, heuristic education could provide an available ground where the creativity of the student can flourish (Bruning et al., 2004; De Leeuw, 1983).

While aggregating with these assertions, De Leeuw (1983) study points out that personality variables and the unfamiliarity of the problem may act also as determinative in how the educational method is received by the student. It shows that students, whose levels of anxiety and fear of failure are high, are more comfortable under algorithmic education, where their actions are more structured and controlled; whereas students who are more autonomous feel more comfortable under heuristic education, where they are given more choices and freedom (De Leeuw, 1983). This state is even more amplified when the problem complexity/unfamiliarity is high and when the problem is unstructured (Leeuw, 1983). As De Leeuw (1983, 45) states, for being able to solve these complex and creative problems, the students should be accustomed to find the solution steps themselves, by being inventive and self-initiative. The less structured, heuristic teaching method gives more opportunity to this kind of a conduct, however De Leeuw (1983, 45) warns that, the students should be first given the necessary self-confidence by means of the certainty and structure given by algorithmic education, only to be gradually set free towards the self-initiativeness and uncertainty of heuristic education. In terms of design students, who could be seen as novice designers, this situation proves to be

even more meaningful, when their levels of anxiety and fear of failure are considered in the face of the unfamiliarity of design problems. As novices do not have the problem-solving strategies and the cognitive ability to retrieve them from their minds without instructions (Casakin, 2005), an algorithmic education at the start would ease their way for the gradual development of their problem-solving abilities towards the attainment of self-initiativeness.

There are several studies that also demonstrate the merits of the use of algorithmic approach for creative problem solving in design education. These studies reveal the creative use of algorithms in design education either by means of integrating a rule-based, algorithmic thinking into design (Gursoy and Ozkar, 2015; Sorguc, 2015; 2005; Uysal and Topaloglu, 2017; Ozkar, 2005), or by means of the use computer algorithms and computational design in design education (Colakoglu and Yazar, 2007; Ozen Yavuz and Yildirim, 2012). Through a course designed to integrate algorithmic thinking in architectural design and education, Sorguc (2005) study demonstrates how algorithmic thinking increases the ability of dealing with complex problems and supports the design ability and creativity of students by improving design solutions. By means of tessellation and pattern studies that are initiated by mapping the rule-based organization of dance choreographies to the medium of two- and three-dimensional design, Sorguc (2015) also shows that rule-based relationships and algorithmic thinking can be generative in design and enables the designer to deal with complexity in the creation of design products that bear unpredictability and complexity. Gursoy and Ozkar (2015) study also demonstrates that a rule-based approach can result in controlled yet creative outcomes in design that might guide design education by attempting to integrate the algorithmic thinking with hands-on design experience. By means of a method proposed for manipulating sheet materials manually in a rule based, algorithmic manner, they show that various formal alternatives that depend on the change of the material's physical characteristics can be formed (by the technique of Dukta) (Gursoy and Ozkar, 2015). The potentials of algorithmic thinking are also shown by the use computer algorithms in design education. In their study that demonstrates the creative use of computer scripting, Colakoglu and Yazar (2007) explain the outcomes of a course they have designed, where the students coded their design intentions to an algorithmic script by using CAD scripting tools, and assert that computational design can act as an innovative approach in design education (Colakoglu and Yazar, 2007).

The creative use of algorithms also demonstrates themselves in basic design education. In their study that shows how a hybrid education that combines the hands-on 'learning by doing' method of basic design tradition with the systemic understanding of computational design, Uysal and Topaloglu (2017) demonstrate that the computational, systemic approach might result in creative solutions in basic design course by means of hands-on experimentation. Likewise, Ozkar (2005) study integrates the computational, algorithmic logic into basic design course without the use of computers, and proposes that, although design has its own non-mechanical way of reasoning that uniquely possesses uncertainty, design education can nevertheless benefit from the rule-based, intelligible understanding of computation, in the development of student designs and in the explanation of design reasoning to students. The potentials of algorithmic thinking by the use computer algorithms is also suggested for Basic design education. In their study that shows the results of the use of a computer algorithm by

students in basic design course, Ozen Yavuz and Yildirim (2012) suggest that since the parameters and rules of this algorithm can be manipulated by the student, the algorithm does not limit the thinking freedom of the students but instead increases their creative perception, as it presents multiple compositional alternatives.

Consequently, the literature displays multiple aspects about heuristic and algorithmic methods, either as methods of problem solving or as methods of education, that have different potentials for the areas of problem solving, creativity and design education. On the basis of this theoretical review, the following analysis will attempt to compare the impacts algorithmic and heuristic educational methods in basic design course in order to assess their relative potentials.

A COMPARATIVE ANALYSIS OF ALGORITHMIC AND HEURISTIC EDUCATIONAL METHODS IN BASIC DESIGN EDUCATION

This analysis has been carried out in the first-year basic design studio with an attempt of making a comparison between the impacts of algorithmic and heuristic educational methods, over of the creativity levels of design projects. The analysis was made on the pre-final projects of Fall 2016-2017 and Fall 2017-2018 semesters, which were executed respectively by means of algorithmic and heuristic educational methods. The algorithmic and heuristic methods were implemented both in the preparation of design assignments and in the educational approach that revealed itself in the guidance of students via critiques. In Fall 2016-2017 semester that was under algorithmic method, the design assignments were more descriptive in terms of the types of design elements to be used (point, line, plane or volume), their characteristics (size, shape, color and texture), numbers, and methods of using them (folding, bending etc.); and in terms of the types and characteristics of the materials. In Fall 2017-2018 that was under heuristic method, a more flexible attitude had been adopted for giving students more initiative in their design decisions, and the design assignments incorporated more freedom both in the types of design elements to be used, their characteristics, numbers, and methods of use, and also in terms of the types and characteristics of the materials (5). The educational approach was also more prescriptive in the algorithmic education, guiding the student to the solution by means of explicitly delineated procedures and demanding from the student the exact formal/geometrical rules or operations that were used in the development of design. The heuristic educational approach, on the other hand, gave more freedom and initiative to the student and took a less structured approach both in the guidance of the student and the demanded responses from him/her.

5. For instance, in the second assignment (about the whole and parts relationship), as to be more descriptive in terms of design elements and materials in algorithmic education, the students were asked to create a two-dimensional design by assembling five shapes on an A3 sheet of paper, which would be chosen out of rectangle, circle and triangle; would be used at least once; and would be cut out from achromatic paper. In the same assignment in heuristic education, on the other hand, the students were again asked to create a two-dimensional design by assembling multiple shapes on an A3 sheet of paper, but they were given flexibility in the type and number of shapes they would select, and were set free in the selection and color of their materials.

The overall framework of the course was developed in line with the educational requirements of basic design studio as outlined in the literature (Teymur and Dural, 1998; Denel, 1979; Bayraktar et al., 2012). The course attempts to introduce the students the basic elements, concepts, and principles of design. It aims to familiarize students with the conceptual elements of design (point, line, plane, volume, form), visual elements of design (shape, size, color, texture), perceptual laws of visual organization (Gestalt principles of figure and ground, whole and parts, proximity, similarity, closure, symmetry, continuity, simplicity), principles of design (unity, repetition, rhythm, contrast, balance, dominance, hierarchy), and formal and spatial characteristics (scale and proportion, solids and

Concept/Principle to be Discussed:	Assignment Number:	Assignment Type:	Assignment Set:
Design concepts and principles I: Figure and Ground	1	2 Dimensional	Set 1
Design concepts and principles II: Whole and Parts	2	2 Dimensional	
Design concepts and principles III: Abstraction	3	2-3 Dimensional	
Design concepts and principles IV: Rhythm and Repetition	4	3 Dimensional	Set 2
Design concepts and principles V: Contrast and Similarity	5	3 Dimensional	
Design concepts and principles VI: Balance	6	3 Dimensional	
Design concepts and principles VII: Hierarchy or Dominance Pre-Final Assignment: Spatial Design for A Living Being	7	3 Dimensional	Set 3
Final Assignment: Spatial Design in a Context for Human Being/s	8	3 Dimensional	

Table 1. Outline of assignments.

voids). It comprises specific assignments where students are expected to organize design elements consciously and use the principles of design to form compositional unities in two and three dimensions. Overall, the course attempts to create sensitivity towards formal, spatial, functional, conceptual, user-related, and representational values in design.

The course is conducted 8 hours a week, during a 14-week academic semester. Two hours of the course every week consists of theoretical discussions, and the rest takes place by means of evaluations of students' work and supervised hands-on design experience. Students are given eight assignments per semester, where the organizational level ranges from the simplest to the most complex. The assignments are divided into four sets, as seen in Table 1. The first set comprises mostly two-dimensional assignments, focusing on the basics of composition, and the second set comprises three-dimensional assignments, focusing on design principles. The third set, which is also the subject of this analysis, comprises a single three-dimensional assignment under the title of "A Spatial Design for A Living Being". As the pre-final assignment, it is significant in terms of being the last truly abstract work, where all the educational parameters until then are discussed, such as design elements, design principles, and formal, spatial, functional, conceptual, user-related, and representational characteristics. The fourth set is the final assignment under the general title of "A Spatial Design in a Context for Human Being/s", where, alongside the previously discussed topics, the students are expected to work with context and topography, as they are designing spaces for human being/s.

The pre-final assignment was selected as the subject of this analysis since it was the last truly abstract work that was comprehensive enough to let us talk about all the educational requirements of basic design course. In both semesters, the assignment asked the students to design a hub for a living being, which would be used as a seclusion station for resting and contemplating. The hub would exist at a gravity-free zone, it would have to take in enough light, and would have to have at least 3 entrances, which would be connected to the seclusion space/s via transition zones. The spaces had to have a good amount of diversity, and there had to be a flow between them. Moreover, the seclusion space/s had to be visible even from afar; therefore, the design principle of hierarchy or dominance was expected from the students to make the seclusion space more noticeable.

The first difference attributed between the algorithmic and heuristic semesters was the identity of the user. In Fall 2016-2017 semester, where algorithmic approach was adopted, the assignment was more descriptive in terms of the characteristics and needs of the user. It would be an intelligent life form in the shape of a sphere with a diameter of 15 cm, who traveled by flying/floating, did not have arms and feet, and had to be charged by means of light. In Fall 2017-2018, where heuristic approach was adopted, the user was to be the Little Prince, who would use this hub during his travels at the outer space. The students were asked to read the book Little Prince and form their own interpretations about his needs, wishes and characteristics for determining the characteristics of the space.

The other difference attributed between the algorithmic and heuristic semesters was about the definition of design elements/requirements and selection of materials. Just as in the characteristics and needs of the user, the assignment was more descriptive in terms of these attributes in Fall 2016-2017 semester. In terms of design requirements, the students were asked to use only planes for creating the solids and voids of their hubs. In terms of materials and techniques, they were required to use thin grey cardboard for their planar elements and had to paint them with gouache color in accordance with their design aims. In Fall 2017-2018, on the other hand, they were totally left free in terms of design requirements and selection of materials, and as such they were given more initiative in their overall design approach.

In both semesters, the assignment started with the development of the conceptual framework for the design, and progressed with the preparation of scaled models and orthographic drawings. The assignment lasted for two weeks and ended with a jury with the participation of course instructors and jury members from the faculty. The number of submitted projects for the assignment were 63 in Fall 2016-2017 semester, and 67 in Fall 2017-2018 semester. The main evaluation criteria used in the assessment of projects were under 6 major headings, which were the formal, spatial, functional, conceptual, user-related, and representational characteristics. These were further detailed in relation to assignment requirements into 13 sub-criteria, as seen in Table 2. Among these criteria, the order and unity of formal organization, space definition and quality, the diversity and flow of spaces, realization of design principles, and compliance with user scale were given special importance.

The comparative analysis of the pre-final assignments of Fall 2016-2017 and Fall 2017-2018 semesters was designed for observing which educational method, algorithmic or heuristic, was more fruitful in fostering creativity in the basic design studio. To be able to observe this, the analysis was designed as to have two stages. In the first stage, an evaluation was made by means of a creativity assessment model developed by the author, which was based on the evaluation of creativity according to products (rather than the person, process, and press). The analysis was attempted to observe the creativity levels of the projects for the selected assignment for each semester. The assessment model was developed as based on Sternberg and Lubart's creativity definition for products, which defined creativity as "the ability to produce work that is both novel and appropriate" (Sternberg and Lubart, 1999). The two criteria in Sternberg and Lubart's creativity definition for products, which are novelty and appropriateness, became the two main parameters of this analysis. The novelty and appropriateness

Assignment Evaluation Criteria	
Main Criteria	Sub-Criteria
Formal characteristics	Design Element Selection and Use
	Order and Unity of Formal Organization
	Three Dimensionality of Formal Organization
	Level of Complexity of Formal Organization
	Realization of Design Principle
Spatial characteristics	Space Definition and Quality
	Spatial Diversity and Hierarchy
	Flow of Spaces
Functional characteristics	Fulfillment of Project Requirements: light intake, minimum number of entrances, visibility of entrances, existence of entrance spaces, existence of transition spaces, existence of seclusion space/s, sufficiency of the sealing character of seclusion space, noticeability of seclusion space.
Conceptual characteristics	Design Idea and Realization
User-related characteristics	Compliance with User Scale
	Compliance with User Needs: getting enough light, finding entrances easily, transiting, and using the spaces comfortably, feeling secluded in seclusion space.
Representational characteristics	Selection and Use of Materials, Use of Color, Use of Texture, Construction Technique

Table 2. Assignment evaluation criteria.

Creativity Assessment Model		
Main Parameters	Sub-parameters	
Novelty (of)	Formal characteristics	Design Element Selection and Use
		Order and Unity of Formal Organization
		Three Dimensionality of Formal Organization
		Level of Complexity of Formal Organization
		Realization of Design Principle
	Spatial characteristics	Space Definition and Quality
		Spatial Diversity and Hierarchy
		Flow of Spaces
	Functional characteristics	Fulfillment of Project Requirements
	Conceptual characteristics	Design Idea and Realization
	User related characteristics	Compliance with User Scale
		Compliance with User Needs
	Representational characteristics	Selection and Use of Materials, Use of Color, Use of Texture, Construction Technique
Appropriateness (of)	Formal characteristics	Design Element Selection and Use
		Order and Unity of Formal Organization
		Three Dimensionality of Formal Organization
		Level of Complexity of Formal Organization
		Realization of Design Principle
	Spatial characteristics	Space Definition and Quality
		Spatial Diversity and Hierarchy
		Flow of Spaces
	Functional characteristics	Fulfillment of Project Requirements
	Conceptual characteristics	Design Idea and Realization
	User related characteristics	Compliance with User Scale
		Compliance with User Needs
	Representational characteristics	Selection and Use of Materials, Use of Color, Use of Texture, Construction Technique

Table 3. Creativity assessment model.

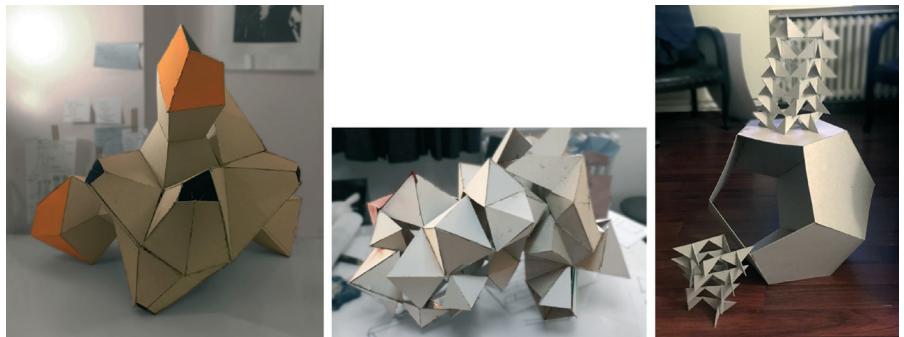


Figure 1. Fall 2016-2017 Semester: Project A08-high novelty scale (left), Project A58-medium novelty scale (middle), Project A39-low novelty scale (right)



Figure 2. Fall 2016-2017 Semester: Project A04-high novelty scale (left), Project A42-medium novelty scale (middle), Project A30-low novelty scale (right)



Figure 3. Fall 2017-2018 Semester: Project B58-high novelty scale (left), Project B63-medium novelty scale (middle), Project B60-low novelty scale (right)

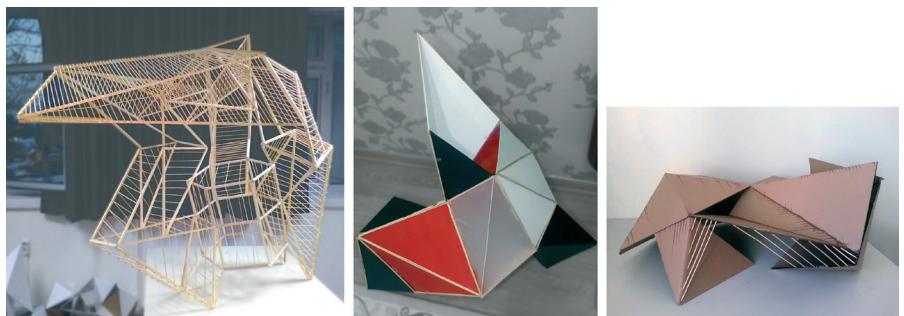


Figure 4. Fall 2017-2018 Semester: Project B39-high novelty scale (left), Project B41-medium novelty scale (middle), Project B19-low novelty scale (right)

indices were further detailed and expanded into sub-parameters by including the project evaluation criteria of the studio, as seen in Table 3.

The projects were analyzed according to these parameters specified in the creativity assessment model, by means of a 5-point scale (**Table 3**). The aim in this analysis was to observe which semester had higher overall creativity levels and higher points in terms of their novelty and appropriateness scales. As novelty could be evaluated in comparison to the other solutions proposed for that same problem (Ruscio and Amabile, 1999); in this assignment, the novelty of projects was assessed in comparison to the solutions that were frequently encountered within the class,

and according to how the sub-parameters were ingeniously sustained. Following the model, novelty of each project was evaluated in terms of their novelty of formal, spatial, functional, conceptual, user-related, and representational characteristics, over a 5-point scale. Appropriateness of projects, on the other hand, was assessed as based on their levels of sustaining the sub-parameters of the assessment model. Again, following the model, appropriateness of each project was evaluated in terms of their appropriateness of formal, spatial, functional, conceptual, user-related, and representational characteristics, over a 5-point scale. As a result of the analysis, an evaluation was made as to bring forward which semester had higher indices of creativity as per their novelty and appropriateness scales.

In the second stage of the analysis, the grade distributions of the pre-final assignments were analyzed for each semester. This stage was thought to provide an insight about the success of each semester in terms of their levels of creativity and design ability, by means of comparing the number of outstanding projects, the number average level projects, the number of unsuccessful projects, and the mean value of grades for each semester. The results of these analyses will be explained further in detail in the next section.

RESULTS AND DISCUSSION

The results of the first analysis, which evaluates the creativity levels of the projects, show that the total novelty percentage of projects of Fall 2016-2017 semester with the algorithmic approach, is slightly lower (% 50 of total points from novelty and % 50 of total points from appropriateness) (**Figure 5**) in comparison to the total novelty percentage of the projects of Fall 2017-2018 semester with the heuristic approach (% 51 of total points from novelty and % 0.49 of total points from appropriateness) (**Figure 6**). When the sub-parameters of novelty and appropriateness are further analyzed, it is seen that the projects of Fall 2016-2017 semester, had their novelty scales mostly from representational (% 18.34), formal (% 17.99) and spatial characteristics (% 16.74); and had their appropriateness scales mostly from formal (% 19.61), spatial (% 17.57), and functional characteristics (% 17.04) (**Figures 7 and 8**). The projects of Fall 2017-2018 semester, on the other hand, had their novelty scales mostly from spatial (% 17.52), representational (% 17.52), and formal characteristics (% 17.14); and had their appropriateness scales mostly from representational (% 18.05), conceptual (% 17.11), and user-related characteristics (% 16.48) (**Figures 10 and 11**).

The results of this first analysis also demonstrate that the sum of the novelty percentages of two important characteristics for the assignment, which are the formal and spatial characteristics, is almost the same for both semesters (%34.73 and % 34.66 respectively). Yet it is also seen that the

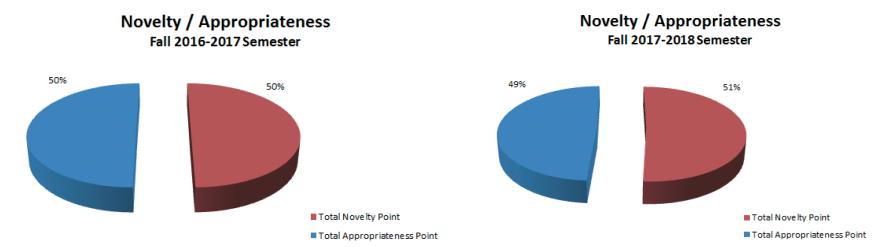


Figure 5 and 6. Novelty-Appropriateness percentages in Fall 2016-2017 semester (left) and Fall 2017-2018 semester (right)

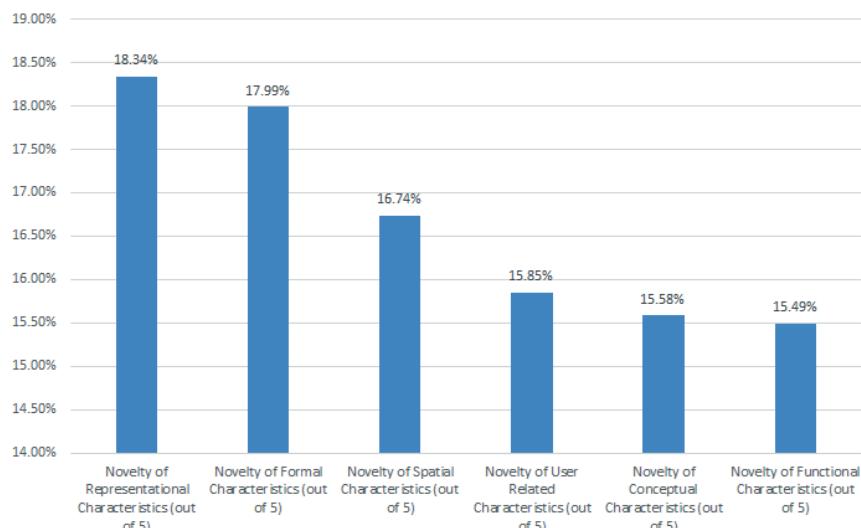


Figure 7. Novelty percentages of total points for Fall 2016-2017 semester.

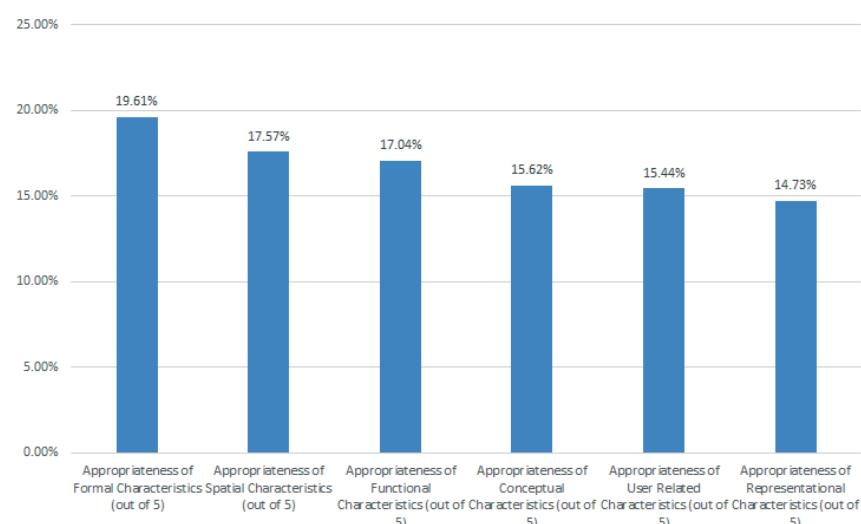
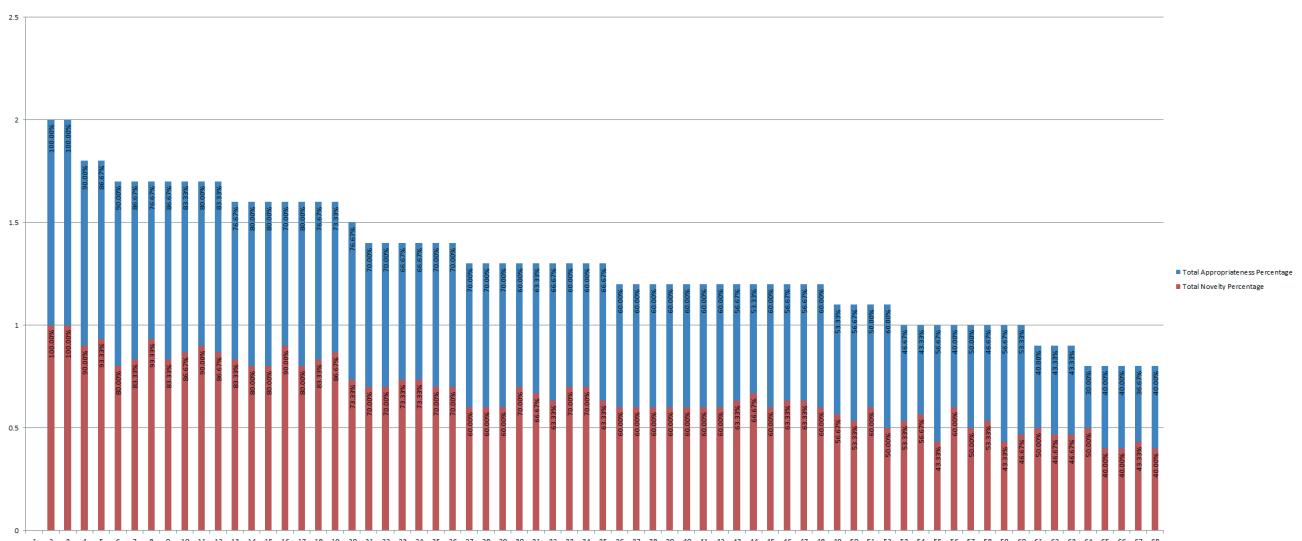


Figure 8. Appropriateness percentages of total points for Fall 2016-2017 semester.

Figure 9. Appropriateness/novelty percentages for each student for Fall 2016-2017 semester.



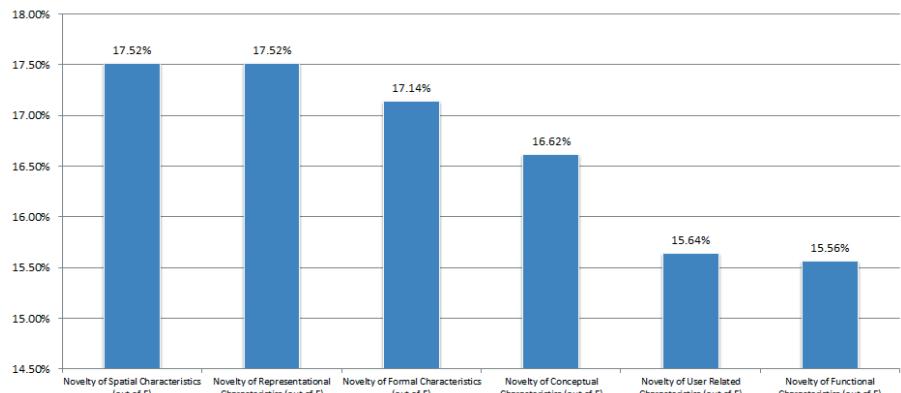


Figure 10. Novelty percentages of total points for Fall 2017-2018 semester.

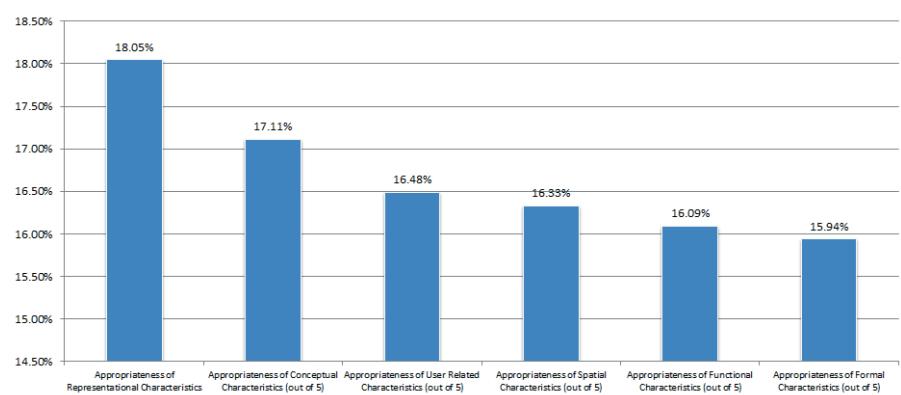
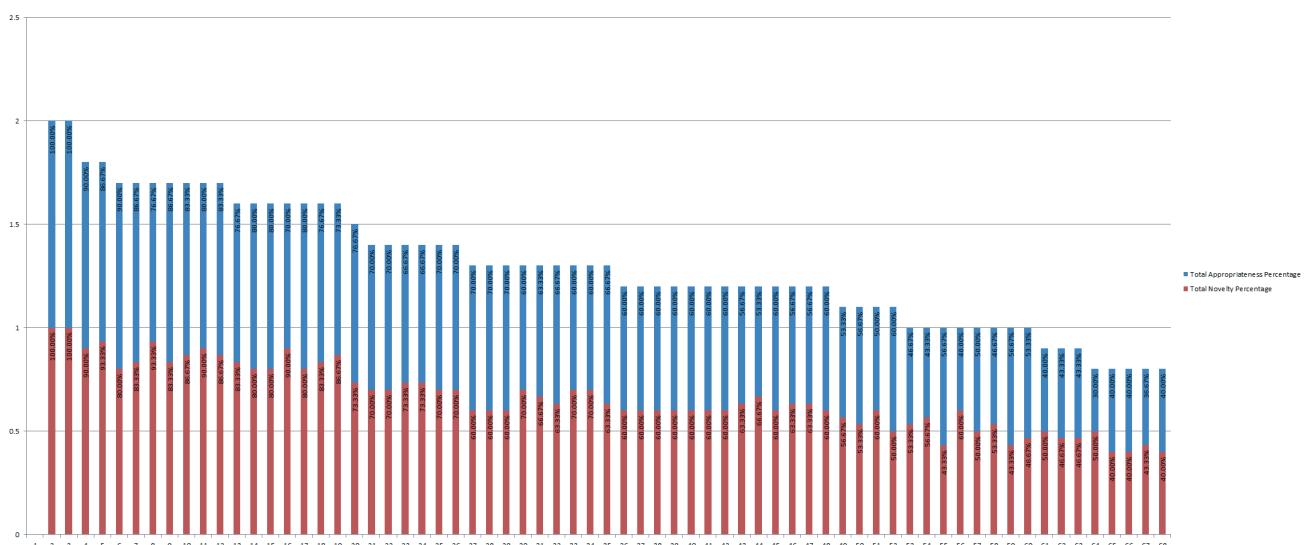


Figure 11. Appropriateness percentages of total points for Fall 2017-2018 semester.

novelty percentage of spatial characteristics is slightly higher in Fall 2017-2018 semester with the heuristic approach (% 17.14), in comparison to Fall 2016-2017 semester with the algorithmic approach (% 16.74) (**Figures 7 and 10**). When the novelty and appropriateness percentages of each project are observed (**Figures 9 and 12**), it is seen that the percentages reach to slightly higher points in Fall 2017-2018 semester with the heuristic approach (% 100), in comparison to Fall 2016-2017 semester with the algorithmic approach (% 93.33) (**Figures 7 and 10**). The lowest novelty percentages

Figure 12. Appropriateness/novelty percentages for each student for Fall 2017-2018 semester.



are also higher in Fall 2017-2018 semester (% 40.00), than Fall 2016-2017 semester (% 23.33) (**Figures 7 and 10**).

The results of the second analysis, which shows the grade distribution for each semester, show that the grades of Fall 2017-2018 semester with the heuristic approach were higher than the grades of Fall 2016-2017 semester with the algorithmic approach (**Figures 13 and 14**). Fall 2016-2017 semester had lesser outstanding grades (% 0.0 of 90-100 and % 3.17 of 85-89), more failing grades (% 7.94 of 35-44 and % 9.52 of 0-34), and lesser value of grade averages (average grade segment of the class is 50-59 with % 26.98) (**Figure 13**). Fall 2017-2018 semester, on the other hand, had more outstanding grades (% 5.97 of 90-100 and % 10.45 of 85-89), less failing grades (% 4.48 of 35-44 and % 0.00 of 0-34), and higher value of grade averages (average grade segment of the class is 60-69 with % 32.84) (**Figure 14**).

In accordance with these results, the projects of Fall 2017-2018 semester with the heuristic educational method demonstrated higher novelty levels in terms of their design element selection and use, level of complexity of formal organization, space definition and quality, spatial diversity and hierarchy, flow of spaces, design idea and realization, selection and use of materials, use of texture, and selection of construction technique (**Figures 3 and 4**), in comparison to the projects of Fall 2016-2017 semester with the algorithmic educational method, which fell short on trying novel methods and means for exploring and defining these characteristics (**Figures 1 and 2**).

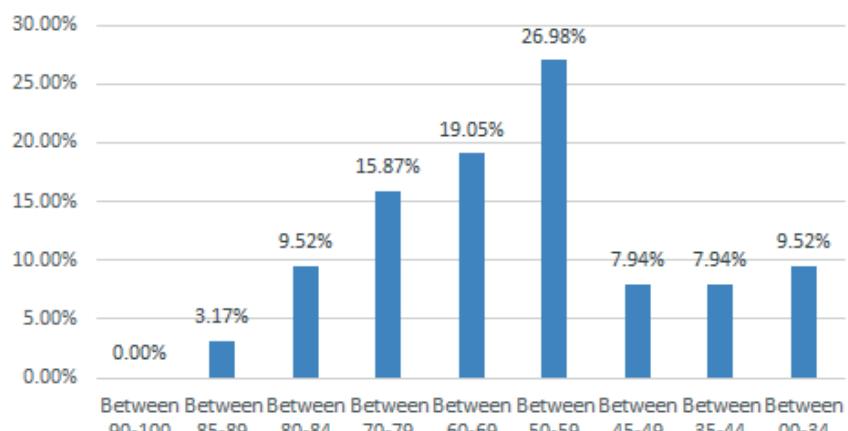


Figure 13. Grade distribution for Fall 2016-2017 semester.

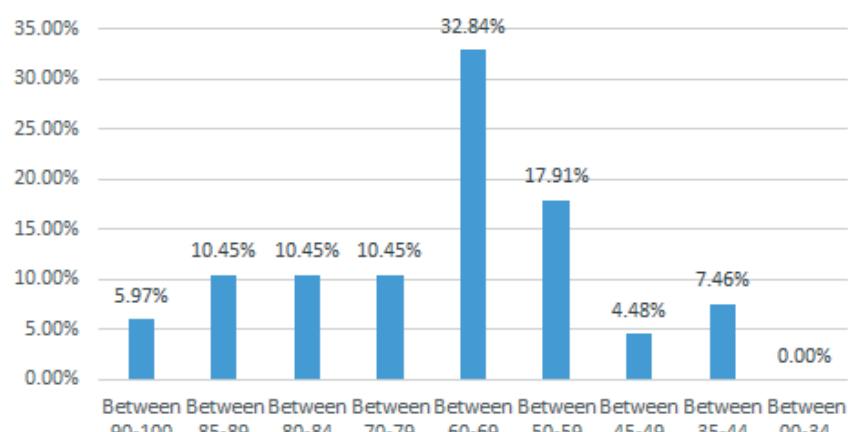


Figure 14. Grade distribution for Fall 2017-2018 semester.

These results display two important outcomes regarding the impact of algorithmic and heuristic education in basic design course. Firstly, it is seen that heuristic education had a slightly more positive effect for the overall novelty levels of the projects than algorithmic education. Secondly, it is observed that heuristic education increased the standard level of the projects by positively affecting the value of the average grades. Based on these results, this study might imply that heuristic education would affect the overall creativity levels of projects in a positive way, and suggest that students who are educated with a flexible heuristic approach in basic design course would be able to show more exploratory behavior, generating more novel solutions than students who are educated with algorithmic approach.

CONCLUSION

This paper has investigated the impact of algorithmic and heuristic educational methods in basic design course in an attempt to observe their effects on the development of the creative cognition of students on the basis of the creativity levels of their projects. The research indicated that the type of educational method that is used in design could make an actual difference in the development of the creative problem-solving ability of students and displayed that the heuristic educational method could affect the creativity levels of students in a more positive way than the algorithmic educational method. It displayed that under the heuristic educational method, both the overall novelty levels of the projects and also the average grade value of the class were higher in comparison to the algorithmic educational method. Students who were educated heuristically showed more exploratory behavior and were able to generate more novel solutions to the design problem at hand than students who were educated algorithmically.

These results might imply that heuristic educational method would be effective in basic design education for increasing students' ability to behave in a more flexible, creative and exploratory manner in the face of the novel problems that they encounter. By giving students flexibility and freedom in their design decisions, heuristic education would be able to support the self-directedness and autonomy of students, which is much needed to deal with the complex problems of the contemporary design practice. Through heuristic method, basic design education, or architectural education in general, could promote the students to have more active minds to be able to deal with the uncertainties of design problems (Findeli, 2001). In this sense, heuristic educational method could be seen as an asset of architectural education, which could be operative in the quest of dealing with the complexities of the profession.

The examination of heuristic and algorithmic educational methods in design could be broadened by further research as to include the person, process, and the press (environment) dimensions of creativity as well. Future studies could examine the effects of heuristic and algorithmic educational methods by focusing on the thinking and learning styles of the studied subjects (person), the effects of the creative environment on subjects (press), and the differences in the design processes of subjects (process), in order to better understand and set forth the authentic characteristics of both of these educational methods.

ACKNOWLEDGMENTS

The author is deeply grateful to many people for their valuable contributions in the formation of this work: her course colleagues in Fall 2016-2017 and 2017-2018, Çiğdem Yilmaz Altürk, Sila Çankaya, Sila Karataş Başoğlu, Mehmet Ali Ataç, Şafak Sakçak, Merve Eşmebaşı; Dean of the Faculty of Architecture, Prof. Dr. Ali Turel; Chair of the Department of Architecture, Assoc. Prof. Dr. Gulsu Ulukavak Harputlugil; friends and colleagues, Assoc. Prof. Dr. Timucin Harputlugil, Assoc. Prof. Ezgi Kahraman, Assoc. Prof. Dr. Guzden Varinlioglu, Assist. Prof. Dr. Deniz Altay Kaya, Instr. Dr. Rabia Cigdem Cavdar, Instr. Sinan Kinikoglu; our students of Fall 2016-2017 and 2017-2018; and Ozgur Urey, for all the vital support and encouragement. The author is also grateful to the reviewers for their valuable comments in the development of this study.

BIBLIOGRAPHY

- AKIN, O. (2001) Variants in Design Cognition, *Design Knowing and Learning: Cognition in Design Education*, eds. C. Eastman, W. Newstetter, M. McCracken, Elsevier Books, Oxford.
- BAYRAKTAR, N., GÖRER TAMER, N., TEKEL, A., GÜRER, N., CEYLAN KIZILTAŞ, A., ARMATLI KÖROĞLU, B. (2012) *Görsel Eğitimde Yaratıcılık ve Temel Tasarım*, Nobel Yayıncılık, Ankara.
- BRUNER, J. S. (1960) *The Process of Education*, Harvard University Press, Cambridge.
- BRUNING, R. H., SCHRAW, G., NORBY, M., RONNING, R., eds. (2004) *Cognitive Psychology and Instruction*, Pearson Merrill Prentice Hall, Columbus, Ohio.
- CASAKIN, H. (2005) Design Aided by Visual Displays: A Cognitive Approach. *Journal of Architectural and Planning Research* 22(3) 250-65.
- CASSIDY, S. (2004) Learning Styles: An overview of theories, models, and measures, *Educational Psychology* 24(4) 419-44.
- CHAN CS. (2015) Introduction of Design Cognition, *Style and Creativity in Design, Studies in Applied Philosophy, Epistemology and Rational Ethics*, vol 17. Springer, Cham.
- COLAKOGLU, B., YAZAR, T. (2007) An Innovative Design Education Approach: Computational Design Teaching for Architecture, *METU Journal of the Faculty of Architecture*. 24 (2) 159-168.
- CROSS, N. (2001) Design Cognition: Results from Protocol and Other Empirical Studies of Design Activity, *Design knowing and learning: Cognition in design education*, eds. C. Eastman, W. Newstetter, M. McCracken, Elsevier Books, Oxford; 79-103.
- CROSS, N. (2006) *Designerly Ways of Knowing*, Springer-Verlag, London.
- CSIKSZENTMIHALYI, M. (1994) The Domain of Creativity. *Changing the World: A Framework for the Study of Creativity*, eds. D. H. Feldman, M. Csikszentmihalyi, H. Gardner, Praeger Publishers, London; 135-58.
- DE LEEUW, L. (1983) Teaching Problem Solving: An ATI Study of the Effects of Teaching Algorithmic and Heuristic Solution Methods, *Instructional Science* (12) 1-48.
- DEMIRBAS, O. O., DEMIRKAN, H. (2003) Focus on Architectural Design Process through Learning Styles, *Design Studies*, 24, 437-56.

- DENEL, B. (1979) *A Method for Basic Design*, ODTÜ Mimarlık Fakültesi Yayınları, Ankara.
- EASTMAN, C. (1969) Cognitive Processes and Ill-Defined Problems: A Case Study from Design, *Proceedings of First Joint International Conference on Artificial Intelligence*, Washington D.C.
- EASTMAN, C. (2001) New Directions in Design Cognition: Studies of Representation and Recall, *Design knowing and learning: Cognition in Design Education*, eds. C. Eastman, W. Newstetter, M. McCracken, Elsevier Books, Oxford; 147-98.
- FINDELI, A. (2001). Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion, *Design Issues* 17(1) 5-17.
- FINKE, R. A., WARD, T. B., SMITH, S. M. (1992) *Creative Cognition, Theory Research and Applications*, MIT Press, Cambridge, Massachusetts.
- GENTNER, D., HOLYOAK, K. KOKINOV, B. N., eds. (2001) *The Analogical Mind: Perspectives from Cognitive Science*, MIT Press, Cambridge, Massachusetts.
- GLOBA, A. (2015) *Supporting the Use of Algorithmic Design in Architecture: An empirical Study of Reuse of Design Knowledge*, unpublished PhD Thesis, Victoria University of Wellington, 2015.
- GREEN, L., BONOLLO, E. (2003) Studio-based Teaching: History and Advantages in the Teaching of Design, *World Transactions on Engineering and Technology Education*, 2(2) 269-272.
- GÜRSOY, B., ÖZKAR, M. (2015) Visualizing Making: Shapes, Materials, and Actions *Design Studies*, 41, 29-50
- ITTEN, J. (1975) *Design and Form: The Basic Course at the Bauhaus and Later*, Van Nostrand Reinhold, New York.
- JANSSON, D. G., CONDOOR, S. S., BROCK, H. R. (1993) Cognition in Design: Viewing the Hidden Side of the Design Process, *Environment and Planning B: Planning and Design*, 20(3) 257-271.
- KOLB, D. A. (1984) *Experiential Learning: Experience as The Source of Learning And Development*, Prentice-Hall, Englewood Cliffs.
- LAWSON, B. (1980) *How Designers Think*, Architectural Press, London.
- LAWSON, B. (1994) *Design in Mind*, Butterworth-Heinemann, Oxford, UK.
- MATLIN, M. (2014) *Cognitive Psychology*, John Wiley and Sons, New York.
- MENNAN, Z. (2008) The Question of Non-Standard Form, *METU Journal of the Faculty of Architecture*, 25(2) 171-83.
- ORHON, G. (2014) *Yaratıcılık: Nörofizyolojik, Felsefi ve Eğitsel Temeller*, Pegem Yayıncılık, Ankara.
- OXMAN, R. E. (2004) Think-maps: Teaching Design Thinking in Design Education, *Design studies*, 25(1) 63-91.
- ÖZEN YAVUZ, A., YILDIRIM, T., (2012) Utilization of Digital-Algorithmic Design Tools in Architectural Basic Design Education, *Procedia - Social and Behavioral Sciences*, (51) 307-10.

- OZKAR, M. (2004) *Uncertainties of Reason: Pragmatist Plurality in Basic Design Education*, Unpublished Ph.D. Dissertation, Massachusetts Institute of Technology.
- ÖZKAR, M., (2005) Lesson 1 in Design Computing Does Not Have to be with Computers: Basic Design Exercises, Exercises in Visual Computing, *Education and Research in Computer-aided Architectural Design in Europe (eCAADe) 23 Digital Design: The Quest for New Paradigms*, Lizbon, Portugal; 311-18.
- RENKI, A., HILBERT, T., SCHWORM, S. (2009) Example-Based Learning in Heuristic Domains: A Cognitive Load Theory Account, *Educational Psychology Review* (21) 67-78.
- RHODES, M. (1961). An Analysis of Creativity. *The Phi Delta Kappan* 42(7) 305-10.
- ROGOFF, B. (1990) *Apprenticeship in Thinking: Cognitive Development in Social Context*. Oxford University Press, Oxford.
- RUSCIO, A. M., AMABILE, T. M. (1999) Effects of Instructional Style on Problem-Solving Creativity, *Creativity Research Journal* 12(4) 251–66.
- SALAMA, A. (2015) *Spatial Design Education: New Directions for Pedagogy in Architecture and Beyond*, Ashgate Publication Limited, Surrey, England.
- SCHÖN, D. (1983) *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York.
- SCHÖN, D. (1985) *The Design Studio: Explorations of its Traditions and Potentials*, RIBA Publications Limited, London.
- SCHÖN, D. (1988) Designing: Rules, Types and Worlds, *Design Studies* 9(3) 181-90.
- SIMON, H. A. (1973) The Structure of Ill-Structured Problems. *Artificial intelligence*, (4) 181–201.
- SIMON, H. A., NEWELL, A. (1957) *Heuristic Problem Solving: The Next Advance in Operations Research*, address at the banquet of the 12th National Meeting of the Operations Research Society of America (November 14), Pittsburg, Pennsylvania.
- SORGUC, A., (2005) Teaching Mathematics in Architecture, *Nexus Network Journal*, 7(1) 119-24.
- SORGUC, A., (2015) Dancing with Isometries in Architecture, *Nexus Network Journal*, 17(2) 641-654.
- STERNBERG, R. J. (2007) *Cognitive Psychology*, Thomson Wadsworth, Australia.
- STERNBERG, R. J., LUBART, T. I. (1999) The Concept of Creativity: Prospects and Paradigms. *Handbook of Creativity*, ed. R. J. Sternberg, Cambridge University Press, Cambridge.
- STEVENS-FULLBROOK, P. (2020) *An Introduction to Learning Theories*. Kindle Edition (February 11, 2020)
- SUWA, M., PURCELL, T., GERO, J. (1998) Macroscopic Analysis of Design Processes Based On a Scheme For Coding Designers' Cognitive Actions, *Design Studies* 19(4) 455-83.

- TERZIDIS, K. (2006) *Algorithmic architecture*. Oxford: Architectural Press.
- TEYMUR, N. (1992) *Architectural Education: Issues in Educational Practice and Policy*, Question Press, London.
- TEYMUR, N., AYTAÇ DURAL, T., eds. (1998) *Temel Tasarım/Temel Eğitim*, ODTÜ Mimarlık Fakültesi Yayıncıları, Ankara.
- UCAR, B. (2006) An Assessment of The Architectural Representation Process Within the Computational Design Environment, *Unpublished Master's Thesis*, Middle East Technical University (METU), Ankara.
- UYSAL, V. Ş., TOPALOGLU, F. (2017) Bridging the Gap: A Manual Primer into Design Computing in the Context of Basic Design Education. *International Journal of Art & Design Education*, 36 (1) 21-38.
- WALLAS, G. (1926) *The Art of Thought*, Harcourt Brace and Co, New York.
- WARR, A., O'NEILL, E. (2005) Understanding Design as A Social Creative Process, *Proceedings of the 5th Conference on Creativity and Cognition*, London, UK; 118-27.
- WELLING, H. (2007) Four mental Operations in Creative Cognition: The Importance of Abstraction, *Creativity research journal*, 19(2-3) 163-77.
- WILSON, S. E., ZAMBERLAN, L. (2017) Design Pedagogy for an Unknown Future: A View from the Expanding Field of Design Scholarship and Professional Practice, *The International Journal of Art and Design Education*, 36(1) 106-17.
- YANG, W., DIETRICH, A., LIU, P., MING, D., JIN, Y., NUSBAUM, H. C., QIU, J., ZHANG, Q. (2016). Prototypes are Key Heuristic Information in Insight Problem Solving, *Creativity Research Journal* 28(1) 67-77.
- YILMAZ, S., SEIFERT, C. M., GONZALEZ, R. (2011) Design Heuristics: Cognitive Strategies for Creativity in Idea Generation. *Design computing and cognition '10*, ed. J. S. Gero, Springer, Dordrecht.

Anahtar Sözcükler: Tasarım bilişi; yaratıcılık; algoritmik yöntem; sezgisel yöntem; temel tasarım eğitimi.

TASARIM EĞİTİMİNDE YARATICI BİLİŞİ GELİŞTİRMEK: TEMEL TASARIM EĞİTİMİNDE ALGORİTMİK VE SEZGİSEL EĞİTİM YÖNTEMLERİNİN KARŞILAŞTIRMALI BİR ANALİZİ

Bu araştırma, Temel Tasarım eğitiminde, algoritmik ve sezgisel eğitim yöntemlerinin öğrencilerin yaratıcı bilişlerinin gelişimi üzerindeki etkilerini incelemeyi amaçlamaktadır. Tasarım eğitiminde, yaratıcılığın gelişimi ve yaratıcı problem çözme alanlarında eğitim yöntemlerinin etkisi konusu sınırlı sayıda araştırma ile ele alınmıştır. Algoritmik ve sezgisel eğitim yöntemlerinin Temel Tasarım eğitimindeki etkisi ise henüz araştırılmış degildir. Bu etkiyi araştırmak için, bu çalışma algoritmik ve sezgisel eğitim yöntemlerinin Temel Tasarım eğitiminde kullanımı hakkında hem sistematik bir teorik inceleme hem de nitel bir analiz yürütmektedir. Sistematik teorik inceleme hem tasarım bilişi ve yaratıcılık çalışmalarında hem de tasarım eğitimi çalışmalarında yapılmıştır. Nitel analiz ise, algoritmik ve sezgisel eğitim yöntemlerinin etkisinin, projelerin yaratıcılık duzeyleri üzerinden (yenilik ve uygunluk kriterlerine göre değerlendirilerek) karşılaştırılması amacıyla, ilk yıl Temel Tasarım

stüdyosunda gerçekleştirilmistir. Analizler sırasıyla, algoritmik eğitim metodu ile gerçekleştirilen 2016-2017 Güz dönemi ön-final projeleri, ve sezgisel eğitim yöntemi doğrultusunda gerçekleştirilen 2017-2018 Güz dönemi ön-final projeleri üzerinde gerçekleştirilmistir. Karşılaştırmalı analiz sonuçları, sezgisel gruptaki projelerin hem genel yenilik düzeylerinin hem de ortalama not değerlerinin algoritmik gruptakilere göre daha yüksek olduğunu göstermektedir. Bu sonuçlar, sezgisel eğitimin, projelerin genel yaratıcılık düzeylerini daha olumlu bir şekilde etkileyeceği ve sezgisel olarak eğitilen öğrencilerin, algoritmik olarak eğitilen öğrencilere göre daha fazla keşif davranışını gösterebilecekleri ve daha yeni çözümler üretebilecekleri anlamına gelebilir.

FOSTERING CREATIVE COGNITION IN DESIGN EDUCATION: A COMPARATIVE ANALYSIS OF ALGORITHMIC AND HEURISTIC EDUCATIONAL METHODS IN BASIC DESIGN EDUCATION

This research aims to examine the impact of algorithmic and heuristic educational methods in basic design education in an attempt to see their effects on the development of the creative cognition of students. The impact of educational methods in the development of creativity and creative problem-solving ability in design education has been addressed by a limited number of studies. The impact of algorithmic and heuristic educational methods in basic design education, on the other hand, has not been studied as of yet. In order to investigate this impact, this research conducts both a systematic theoretical review and a qualitative analysis on the use of algorithmic and heuristic educational methods in basic design education. The systematic theoretical review has been conducted both in the studies of design cognition and creativity and also in the studies of design education. The qualitative analysis has been carried out in the first-year basic design studio, with an attempt of making a comparison between the impacts of algorithmic and heuristic educational methods, through a creativity assessment of projects, based on the criteria of novelty and appropriateness. The analysis was made respectively on the pre-final projects of Fall 2016-2017 semester, which was carried out by means of an algorithmic educational method, and Fall 2017-2018 semester, which was carried out in line with heuristic educational method. The results of the comparative analysis have shown that both the overall novelty levels of the projects and also the average grade values were higher in the heuristic group in comparison to the algorithmic group. These results might imply that heuristic education would affect the overall creativity levels of projects in a positive way, and the students who are instructed heuristically would be able to show more exploratory behavior, generating more novel solutions than students who were instructed algorithmically.

ZEYNEP ÇİĞDEM UYSAL ÜREY; B.Arch, M.Arch., PhD.

Received her B.Arch and M.Arch. degrees from the Middle East Technical University, Department of Architecture (1997-2004). Earned her PhD. degree in design from College of Design, North Carolina State University (2012). Major research interests include theories of architectural design, design cognition, creativity, and design pedagogy.
zeynepuysal@cankaya.edu.tr

