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Original Research Article

Developing a Nature-Inspired Model of Creativity in Architectural Design for Novice Learners*

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Abstract

Problem statement: In the architectural design process, creativity plays an essential role in idea processing. Since creative ideas do not emerge without mental background, the ideas of the past contribute to future creations. Given that over years nature has been referred to as a natural selection for its efficiency and diversity, it can serve as a model in the creative process of the architectural design model. This study aims to focus on the creative process, design process and bionic science at the same time. Previous studies have not integrated three components.

Research objective: Since architecture is fundamentally interdisciplinary, this research attempts to highlight the role of design process systems, creativity and bionic science. Then it describes their associations in the conceptual and logical systems. It also attempts to establish a meaningful and purposeful relationship between the above-mentioned elements and concepts. The impetus of this study is to understand how bionics can promote creativity in architectural design. It is hoped that this study serves as a baseline for the nature-inspired process of creative architectural design.

Research method: This research employs logical reasoning and uses analytical-descriptive analysis to establish a relationship between creativity, architectural design and patterns derived from nature. In terms of the purpose, this study is applied and in terms of the type, it is also a review.

Conclusion: The research findings confirm that nature is a suitable platform for improving the visual thinking strategy of beginners to design ideas. The use of visual descriptors as a cognitive strategy leads to visual retrieval of mental latency in the idea generation stage, which leads to design diversity. Knowledge of the components of nature provides us with strategies to experience structures and systems. This helps us gain a better understanding of the problem of architecture and find a variety of solutions. It also enhances the creativity of novice designers. The stages of the design and creativity process promoted by bionic science overlap. The basic stages of the creative design in bionic architecture include a) using a bionic framework for the architectural design problem, b) preparing a checklist of nature based on the problem, c) examining the accuracy of the rating scale of the relationship between this list and the design problem.

Keywords: *Architectural design, Design process, Creativity, Creative process, Nature, Bionics.*

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Introduction

In Iran, educational models are mainly conventional and this has limited Iranian students' scope for creativity (Ahmadabadi Arani, Farajollahi & Abdollahyar, 2017). One of the important tasks of the country's educational system is to select university applicants based on their talents and interests. This issue is of great importance especially for architecture applicants who need to have a good understanding of art and science. Until 1992 the selection of applicants of technical and engineering disciplines was based on aptitude, creativity and related professional skills competencies. From this date onwards, the evaluation of candidates' competencies in the field of architecture has been the same as their technical and engineering counterparts. Even in some educational centers, applicants have not been asked to sit an exam or at some institutional centers, they have been admitted for the course without an entrance exam. As a result, the development of artistic and architectural skills of students, which is mainly associated with students' creativity, has been overlooked. The curriculum of architecture in different faculties of Iran is a combination of humanities, technology and design creativity (Rezaei, Keramati & Dehbashi Sharif, 2018). The importance of these areas varies from one school to another. In architecture, designing is important and its relationship with design knowledge is inevitable (ibid.). According to research, 44% of architecture courses are dedicated to architectural design (Doroudgar, 2009). In most schools of architecture, creativity has a big share of architectural design and especially artistic creativity is one of the basic elements in the design process at the highest stage (Izadi, 2003). Teachers' knowledge of creative thinking and their skills in using appropriate techniques have been identified as important factors fostering the creativity of students (Shaebani, Maleki, Abas por & Saedi por, 2017) Therefore, it is necessary to cultivate architectural students' creativity and ask students to put it into practice. The influence of creative thinking in architectural design is noticeable and the creative process highlights the necessity of creating something new. In creative thinking, the product of thinking is the result of new strategies that have not been discovered by others yet (Seif, 2015).

One of the architectural design methods that have received little attention is the creative use of nature as a source of inspiration and initial idea. Even few existing studies on the use of nature in the design process have overlooked the procedural steps through which novice architectural learners develop their mental creativity. Since architecture is fundamentally interdisciplinary, the purpose of this study is to develop conceptual and logical systems to establish a meaningful and purposeful relationship among the elements and concepts mentioned by highlighting the role of systems in the design process, the process of creativity and bionic science. It is hoped that this system can be used as a basis for the process of creative architectural design with learning from nature.

Accordingly, the research questions will be as follows: In what phases of this process is it important to foster the creativity of novice architectural students? How can the use of nature and through what processor model can trigger creative design ideas in the minds of architectural students? Since architecture is fundamentally interdisciplinary, this study attempts to highlight the role of design process systems, creativity and bionic science. It also describes their associations in the form of conceptual and logical systems and then establishes a meaningful and purposeful relationship between the above-mentioned elements and concepts. It is hoped that this study serves as a baseline for the nature-inspired process of creative architectural design.

This research seeks strategies to improve the creativity of architectural students, using nature, which is based on the three main keywords of the creative process, the architectural design process and bionics. The research attempts to understand how developing a research problem and limiting it, demonstrating

creativity in the design process and developing a model of the creative process of designing the bionic architecture (proposed model) can help architectural students generate creative ideas.

Research questions

1- For developing the mental creativity of architectural novice learners during the design process, what steps of this process are important?

2- How do nature and through what process can evoke creative design ideas in the minds of architectural students?

Literature review

A careful perusal of literature shows that previous research has emphasized one or two keywords (the creative process, the architectural design process and bionics), these studies have not been comprehensive and not considered the influence of all three axes (the creative process, the architectural design process and bionics) Some researchers have investigated the relationship between Islam and wisdom in creativity and bionics (Nari Ghomi, 2018; Maddahi, Davoudi Hosseinizadeh & Fathalikhani, 2018; Shajari & Tabatabai Lotfi, 2016). Another group has focused on the relationship between education and creativity (Mansoorian, 2009; Alipour, Faizi, Mohammad Moradi & Akrami, 2016; Feyzi & Alipour, 2017; Ashraf Ganjouei, Saghafi & Iranmanesh, 2017; Sadram, 2017; Khakzand, Mozafar, Feizi & Azimi, 2009; Ahmadabadi Arani et al., 2017; Azimpoor, Eisavi & Azimpoor, 2017; Tamizi, Soheili & Zabihi, 2018; Bagheri & Mardomi, 2011; Asefi & Salkhi Khosraghi, 2017; Rezaei et al., 2018; Momtahen, Hojat & Nari Ghomi, 2017; Banihashem, Rezaei, Badali & Dana, 2014; Ganji, Niusha & Hedayati, 2012). A series of studies have examined the relationship between nature and creativity (Mozafar, Mehdizadeh Seraj & Mirmoradi, 2009; Alipour et al., 2017; Pesaran, Pourmohammad & Shakiba, 2014; Khakzand et al., 2009; Sharghi & Ghanbaran, 2012; Shafipour Yourdshahi, Kianie & Tabatabaian, 2018). Available studies have focused on the issue of architectural design, training and ideation process (Daneshgar Moghadam, 2009; Sharif & Nadimi, 2013; Kalami & Nadimi, 2014; Shariatrad & Nadimi, 2016; Jabalameli, Mozafar, Karimi & Ghasemi, 2019; Amini, Flamaki & Keramati, 2019; Hadian & Pourmand, 2014; Rezaei, 2014; Kheirollahi, 2013) and creative thinking and creative problem solving (Shaebani et al., 2017; Mahzoonzadeh Bushehri, 2017; Hashemi, Shayan Amin, Hajiyakhchali & Naami, 2017). The closest studies to the present research are reviewed in Table 1 and their findings and their relation with this research are mentioned.

This study shows how nature as a visual stimulus can be a source of structural and metaphorical inspiration and ideation for Bionics and can promote learners' creativity in the architectural design process (Fig. 1).

Research methodology

Logical reasoning is the best method to identify themes that are subjective and objective. Therefore, this research employs logical reasoning and uses analytical-descriptive measures. Using a qualitative approach based on mental process, the author seeks to find a logical and orderly relationship between the process of creativity, the process of architectural design and bionic science. In doing so, rational conclusions and objective logical systems can be obtained from their relations. Therefore, after clarifying the necessary definitions and terms, the relationship between the propositions will be developed. Testing the proposed model is not the concern of this study. This model can be tested in another study and its results can be evaluated.

Theoretical framework and literature review

• Creativity, process and component

Understanding creativity can lead to a proper understanding of its impact on the architectural design process. Creativity has been defined in different ways and from different perspectives. Some scholars have defined it as a process while

Table 1. Findings of previous studies and their relation with the present research. Source: authors.

No	Scholars	Finding of the previous study	The contribution of the previous study to this study
1	Banihashem et al. (2014)	This study with 95% confidence indicates that integrated "learning" affects "creativity".	Integrated learning (combining bionic science and architectural design) fosters creativity.
2	Mahzoonzadeh Bushehri (2017)	Problem-solving skills directly influence creativity and indirectly affect student's creativity through academic self-efficacy.	Problem-solving skills as a main pillar of the architectural design process substantially contribute to developing learner's creativity.
3	Sadram (2017)	A novice designer who has no idea of the designing process, cannot gain an accurate understanding of the design process.	Imitation of nature, as a source of inspiration and learning in the architectural design process, can develop learner's creativity.
4	Ashraf Ganjouei et al. (2017)	Visual stimuli, especially vague images, can be used as an appropriate tool by professors to develop creativity in the design ideation stage.	Nature as a visual stimulus can contribute to architecture learner's creativity.
5	Khakzand et al. (2009)	Visual references can help architects to create professional work and have creative designs.	Nature as a visual reference can contribute to architecture learners' creativity.
6	Pesaran et al. (2014)	Like texts, nature is subject to different interpretations. Nature is recommended for designers.	Different perceptions of nature can result in a variety of architectural designs and promote the designer's creativity.
7	Feyzi & Alipour (2017)	Student's attention to formal features and their superficial understanding highlights the necessity of familiarizing students with the analogy in architectural education.	Using biology in developing the reset problem .
8	Mansoorian (2009)	Nature as a source of creativity and innovation reflects the power bestowed on human beings for education by God.	Due to their multifunctional nature, Biological structures can offer a variety of ideas and foster creativity.
9	Maddahi et al. (2018)	The creativity of human beings can fall on a continuum ranging from habitual to transcendent. Habitual creativity is realized within the limits of imagination and fancy faculties.	Different degree of creativity, imagination and fancy can be used
10	Shariatrad & Nadimi (2016)	In framing the problem, the designers select the important aspects of the problem then define and respond to new problems by finding a connection between aspects.	Selecting and adjusting a useful and appropriate frame is a key step in the design process and comprises a creative aspect.
11	Sharif & Nadimi (2013)	Analysis is a factor contributing to the continuous review of the design process. Its purpose of this review is to find new solutions, evaluate them and make a decision for their selection.	Analysis plays an important role in the design process and is a reciprocal process leading to an innovative solution in design.
12	Sharghi & Ghanbaran (2012)	A deductive and inductive approach to the architectural process along with the nature-inspired principles brings lasting results in architecture.	Using bionic science in the process of architectural design based on deductive and inductive logic.
13	Shajari & Tabatabai Lotfi (2016)	The mental image in the position of imaginary observation and inner inspiration and their expression in the stage of creation, which is also a prelude to the creation of external existence, is creativity.	Reflection of the creator's attributes in the form of intellectual truth or purgatory improve the imagination of the designer and develop their creativity through fancy faculty.
14	Rezaei (2014)	"Analogy" weighting the final form against analytical components based on the designer's imagination and fancies, is one of the main factors contributing to form and space.	With the help of "analogy" in the stages of analysis and synthesis, can result in purposeful creativity in the production of form.
15	Kheirollahi (2013)	Drawing, not framed by any design principles, can promote the evaluation of creative ideas before the production Scientific creativity is pervasively updated throughout the design process and its product and mainly as a process, guides the evolution of design.	Imaginary drawings, which set the mind free the liberation of the mind foster students' ability in expressing creativity and the creative idea can be seen as an innovative design.

Rest of Table 1.

16	Tamizi et al. (2018)	Engaging students in corrections and drawing their attention to divergent thinking can increase their creativity in the design process.	The process of architectural design requires creativity and its continuous use in this process is essential.
17	Rezaei et al. (2018)	Scientific creativity substantially influences the whole design process and its product. Creativity as a process guides the evolution of design.	The importance of architectural creativity in the architectural design process.
18	Amini et al. (2019)	A set of individual motifs forms the characteristics of the imaginary space and in the design process, the designer is in a constant transition between this space and the physical space.	The designer can personalize his nature-driven design based on his imagination and fancy and use it as a source of inspiration in developing architectural design thinking.
19	Momtahen et al. (2017)	Following a model is what differentiates the traditional view of creativity from the modern view Creation from nothing is a modern ideal, but the creative act in response to the question of architecture makes sense.	Using a model (e.g. nature) properly can develop learners' creativity and provide a good solution to the problem.
20	Asefi & Salkhi Khosraghi (2017)	Knowing how students learn increases the creative performance of novice learners of architecture.	Learning from nature plays a key role in learner's creativity during architectural design.

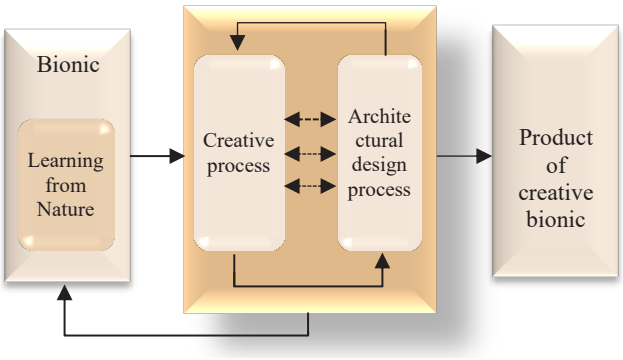

Fig. 1. The integration of creativity, architectural design, and bionics. Source: authors.

others have conceptualized it either as a result or a product. In some definitions, the emphasis has been on the idea and value production (Stein, 1974; Weisberg, 2006; Vernon, 1989; Kaufman & Sternberg, 2010; Kerr & Gagliardi, 2003) and some have considered creativity as problem-solving and achieving new answers, solutions and relationships (Rezaei, 2014; Mahdavinejad, Mahdavinejad & Silvayeh, 2014; Momtahen et al., 2017; Guilford, 1966; Torrance, 1966; Lang, 2007; Eysenck, Arnold & Meili, 1975). The attributes such as novelty, unconventional, unpopular, unique, originality of ideas, answers, solutions and relationships, has been frequently highlighted in most definitions.

Creativity can increase the designers' sensitivity to the problem design and help them propose diverse and unique solutions (Maseleno, Hardaker, Sabani & Suhaili, 2016). A perusal of previous research suggests that though there are different perspectives on the creativity construct, they share some similarities in terms of its components, for example, Guilford and Terence have conceptualized creativity from a cognitive perspective. Guilford introduced initiative (i.e. new responses), fluidity (i.e. multiplicity of ideas) and flexibility (i.e. a variety of responses) as components of creativity and then later Terence added the ability to expand (i.e. the ability to pay attention to detail and implementation of the idea) to the three components mentioned above (cited in Ganji, Sharifi & Mirhashemi, 2005). For Adams, creativity consists of three components of expertise, motivation and creative thinking skills (cited in Garmabi, 2016). According to Amabile (1988), creativity has been derived from subject-related skills, creative thinking skills and intrinsic motivation. Plesk also introduces creativity as a construct with three components of attention, avoidance and mobility and proposes its underlying indicators (Mahdi Hosseini, 2013). In Islamic sources, creativity has cognitive, motivational and personality-associated components (Maddahi et al., 2018). Previous researchers have introduced

models for creative design to improve the aspects of creativity in the process of architectural design. The most important models are detailed in Table 2.

According to Table 2, there is a consensus on five main processes of creativity, unconscious mind and initial perception (problem identification), preparation (conscious effort for developing a solution), incubation (unconscious effort), illumination (unconscious emergence of ideas), denial and verification (conscious development). These five stages overlap with the five phases of the design process mentioned earlier.Every creative idea always has a history behind it. This means that even creative and innovative ideas that are original have been driven by the ideas in the past (Weisberg, 2006). Using existing knowledge as a basis for developing

Table 2. Theorists' conceptualization of the creative design process over time. Source: authors.

Scholars	Creative design process						
	1	2	3	4	5	6	7
Wallas (1926)	Preparation	Incubation	Illumination	Verification	×	×	×
Osborn (1953)	Truth-seeking	Ideation-seeking	Problem-solving	×	×	×	×
Guilford (1966)	Fluidity	Flexibility	Innovation	×	×	×	×
Stein (1974)	Making hypothesis	Testing hypotheses	Transferring results	×	×	×	×
Peilloux & Botella (2016)	Preparation	Imagination	Development	Action	×	×	×
Barron (1988)	Truth-seeking	Problem-solving	Ideation-seeking	Solution-finding	Agreement (critique and evaluation)	×	×
Torrance (1966)	Dealing with the problem	Proposing multiple answers	Identifying the possible solutions	Making hypotheses			×
Amabile (1988)	Task presentation	Preparation	Generation of possible response	Validation	Assessment	×	×
Nadimi (1991)	Making harmonious concepts	Making multiple visual designs	Selecting and expanding the main design	×	×	×	×
Ghasemzadeh (1996)	Problem-solving	Truth-seeking	Problem identifying	Ideation	Selecting and evaluating		
Hojat (2004)	Dynamic education; on-going planning, attention to student role)	Progressive education; unlimited education, hypothetical education	Conscious education; opportunistic training, opportunistic training	Clinical education; in-person education, training	Conceptual education; avoid instances, encourage truth-seeking	×	×
Khakzand et al. (2009)	Seeing and hearing	Testing and perceiving (analysis and review of data). Inspiration from creative designs	Synthesizing	Developing a framework	×	×	×
Tamizi et al. (2018)	Idea production (unconscious mind)	Definition of the idea (design)	Evaluation	Revision and decision	×	×	×

new ideas is important. In areas where human has no sound insight and knowledge, he needs guidance. He is similar to a child who needs to learn how to act and behave in the family and society. An architectural design novice learner can be described as the one who is at the early stage of learning how to design and needs to develop their competency and for this purpose, he needs a strategic plan. He cannot gain a proper understanding of how to design with an empty mind (Sadram, 2017). Knowledge achieved through visual education is more comprehensive and complete than knowledge gained in the teaching-learning process and the insight that is imprinted in the mind through "seeing" is more meaningful than the insight that is obtained through hearing news (Ghodousifar, Etesam, Habib & Panahi Barjai, 2012). Thus, such an understanding helps novice architectural designers to develop creativity in their design process. According to Kneller (1990), familiarity with existing ideas leads to creativity. He considers the existing ideas as a springboard triggering the creative person's thoughts and ideas. "Mulla Sadra" also describes the human soul as the fruit of the body arguing that like the child who needs a mother at the beginning of development, the soul needs nature. Due to the visual nature of design, nature as a visual stimulus can cause the mental imagery of new students to model and be inspired by it (Tayyah, Mehdizadeh Saradj & Mahmoodi Zarandi, 2021). Nature with its many capabilities is a very good source for learning and creative modeling, discovering new strategies to solve design problems. Different aspects of nature can be used as creative means to develop design solutions. Using nature for technology within the bionic framework reduces the gap between the world of human creativity and nature (Mansoorian, 2009), which is itself a form of blended learning and according to researchers, blended learning also affects the creativity of scholars (Banihashem et al., 2014). Therefore, the knowledge in nature can be used as a basis for developing new ideas and trigging creative thinking of novice learners of architectural design.

• Architectural design, its components and process

The scope of the design is too broad to assume a single definition for it. Architecture as a field falling under the broad scale of the design is an analytical process that requires problem discovery, analysis, synthesis, evaluation and selection. Design can be seen as an attempt to invent solutions before their implementation (Lang, 2007). As Lawson (2016) points out, the design process is not a series of clear and recognizable activities that occur in a logical, predictable and definite order. Rather, the process is too complex to develop a general rule for it. According to Table 3, many researchers have attempted to provide a model for the design process. According to Fig. 2 and Table 3, the different proposed steps pursue the same goal and have some features in common, the most important of which are the fluid, nonlinear and reversible process, endless flow and flexibility in the design process. Generally speaking, what is shared by most processes is the existence of five stages, problem discovery, problem-solving (of course, problem discovery and solution can be components of analysis), analysis, synthesis and evaluation. Each stage is as important as the other. This means that a lack of understanding of each stage will make the proceeding to the next stage more difficult. In all stages, creativity is the most important part of this process. As "the design process is based on creative thinking and this purposeful thinking helps the researcher provide an answer to the design problem using creative methods" (Daneshgar Moghadam, 2009). Therefore, creativity and creative thinking serve as a linking ring that links the stages of the design process and leads to the formation of the final design. Separating the design process from the creative process is useless. Studies show that the most important creative parts of the design process occur in the first two stages: 1- Finding and stating the problem; 2- Solving the problem (ideation and initial idea). Lawson (2016) believes that "designers must be skilled in finding and articulating problems, as well as in understanding and examining them". This

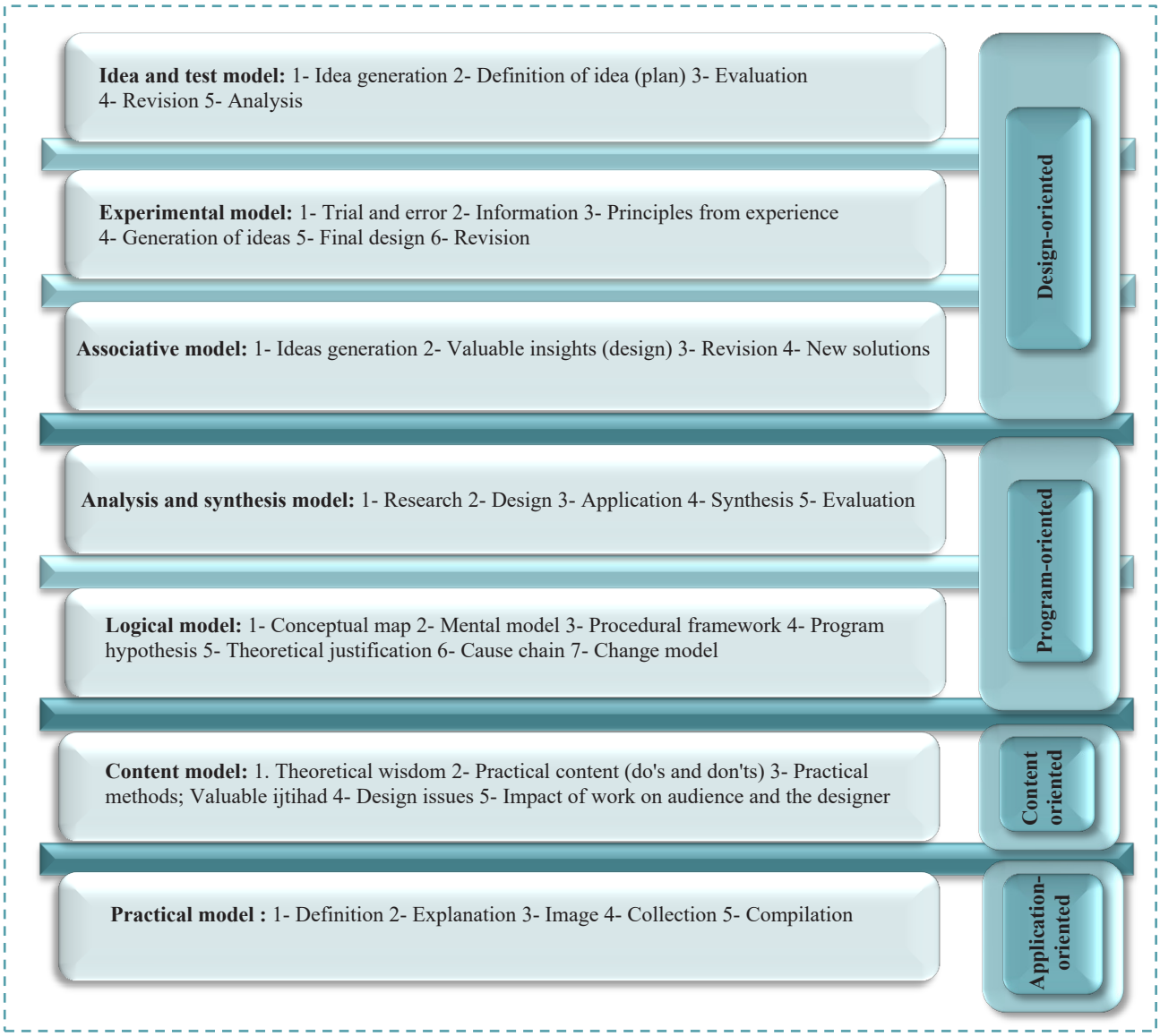

Fig. 2. Design models based on the type of process through the lens of experts. Source: authors based on Bagheri & Mardomi, 2011; Labibzadeh, Hamzehnejad & Mohammadi, 2018; Mardomi & Dehghani Tafti, 2017.

architectural approach focuses on problem-finding; that is, if the design is treated as a problem, the design process will have two aspects: problem identification and solution (Heath, 1984). Thus, finding the problem creatively is the first step shedding light on the path of the architectural design process (Fig. 3).

- Identifying and formulating the problem in architectural design

Finding begins with what Getzels refers to as "problem formulation". According to him, formulation means finding the right problem that is worth answering and is creative. It is believed that a creative solution is a response to a creative problem. In dealing with the design problem, the first step is to frame the problem, this helps the designers to understand a complex and ambiguous design situation by framing it[1] (Shariatrad & Nadimi, 2016). Frame[2] "From a design problem-solving point of view, can be seen as a window into the problem or a way to formulate the problem" (Lawson, 2016). Dorst (1997) believes that framing can be the core of design thinking.

Table 3. Design process through the lens of experts. Source: authors.

Scholars	Designing process						
Wallas (1926)	Preparation	Incubation	Presentation	Correction			
Maver (1970)	Preparation	Incubation	Illumination	Negation	Verification		
Mozaffar & Khakzand (2009)	Representation	Planning	Implementation	Revision			
Rzevski (1980)	Research process (canonical)	Creative process (Analogical)	Rational process (Systemic)				
Royal Institute of British Architecture (1962)	Attraction	Review	Expansion	Presentation			
Markus (1969) Maver (1970)	Main guidelines	General outlines	Detailed plan	Detailed plan	Combination	Decision	Decision
Darke (1978) Cited in Lawson, (2016)	Generator	Conjecture	Analysis				
Lawson (2016)	Analysis	Synthesis	Evaluation				
Asimow (1962)	Problem capabilities	Preliminary design	Detailed design				
Archer (1965)	Planning	Data collection	Analysis	Synthesis	Development	Communication	
Jones (1970)	Disintegration	Amalgamation	Evaluation				
Alexander (1964)	Analysis	Synthesis	Disintegration	Amalgamation			
Roozemburg & Eekels (1995)	Analysis	Synthesis	Simulation	Evaluation with the possibility of repetition of stages			
Oxman (1994)	Representation,	Production	Implementation	Evaluation			
Koberg & Bagnall (1972)	Acceptance	Analysis	Explanation	Imagination	Selection	Implementation	Evaluation
Goel (1995)	Problem formulation	Initial design	Refinement	Detailed design			
Broadbent & Ward (1969)	Evaluation	Composition	Analysis	Information			
Dubberly (2004)	Research	Imagination	Concept development	Prototype	Product		
Kirk (2004) cited in Dubberly (2004)	Problem formulation	Problem	Analysis	Search	Decision making	Representation	
Goldshmidt (1991)	Design requirements	Design modifiers (creative idea)	Design interpretation (selection)				
Hamel (1993)	Breakdown	Combination	Modeling				
Pahl & Beitz (1994) cited in Gorji Mahalbani, Mohammadi, Bahmanesh, Javidi, Iraji & Nasiri (2018)	Clarification	Conceptual design	Visual design	Detail design			
Mahmoodi (2001)	Preparation	Latency	Illumination	Proof			
Gero (1996)	Designing	Transferring a set of information from one state to another					
Cross (1989)	Clarification of the problem	Improvement of details					
Popper (2002)	Planning	Analysis	Evaluation	Combination	Implementation		

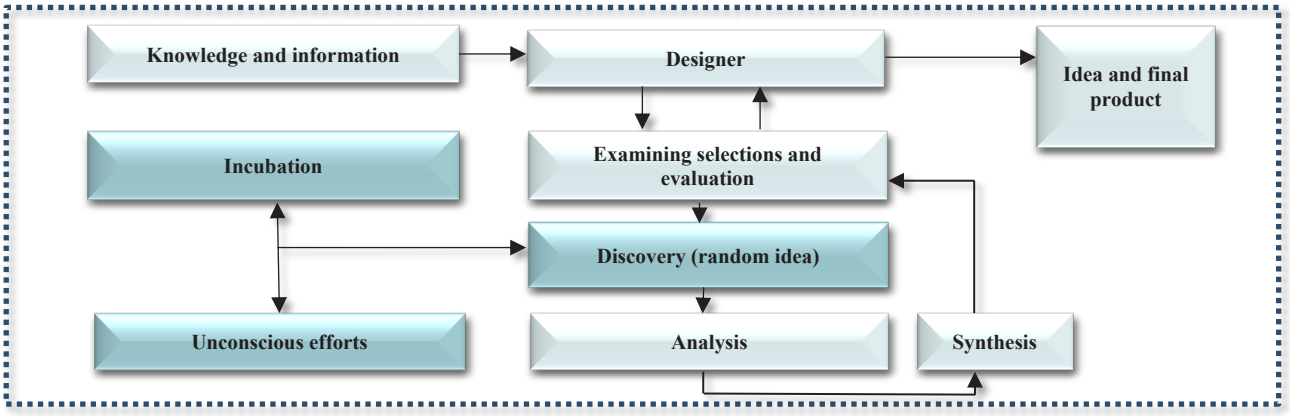

Fig. 3. General stages of the designer's mental structure. Source: authors.

Developing the right framework is a key design step and is one of the pillars of creativity. Most experienced designers have found it necessary to start with a creative approach. Therefore, the most critical time when creativity occurs refers to the time an individual recognizes the problem and enters the clarification stage. If the problem is defined and articulated correctly, half of the problem will be solved. For this reason, some scholars prioritize the problem over designing (Bernsen, 1986). The importance of knowing the problem correctly (which some have called formulation or framing) can be seen in various sources of problem-solving, creativity and innovation (Jabalameli et al., 2019) Providing novice designers with complex and uncertain situations and somewhat ambiguous foster their creativity (Seif 2015 cited in Azimpoor et al., 2017). Most creativity occurs when the problem is imposed from the outside. Indeed, framing the issue itself can lead to creativity. Therefore, according to Lawson, it seems that one of the most important abilities of a designer is to creatively limit the problem and discover it. Using the pattern of nature can limit the problem in the design process.

- Problem-solving (ideas and ideation) in architectural design

After identifying the architectural problem, the designer needs to analyze it based on his understanding and then determine for which parts need to develop the strategies for solution. For this purpose, he needs to review the initial concepts and goals of the design. This is the beginning of ideation[3] . Therefore, designers in general and novice designers, in particular, need to pay much attention to the context of the problem from a special point of view and to frame the problem in a way that can stimulate creativity and result in the initial idea. This means that the designer looks at the problem from a specific angle, approach, or through specific lenses and limits the design problem by the chosen frame. Then considering the principles and criteria related to the subject, he presents the initial idea. One of the most important challenges in the architectural design process is idea generation. Past research shows that in the architectural design process, novice designers have faced more challenges in the problem-solving and ideation stages than in other stages (Nadimi & Shariatrad, 2012; Kalami & Nadimi, 2014; Khakzand et al., 2009; Alipour et al., 2017). Problem-solving ability is a motivating factor contributing to creativity (Mahzoonzadeh Bushehri, 2017). Problem-solving is a cognitive process through which the researcher seeks to find the right solution to achieve the goals of the project. This process is an integral part of creativity. Fig. 4 shows the steps of discovering and solving a problem in the designer's mental structure.

In literature, the initial idea has been mentioned

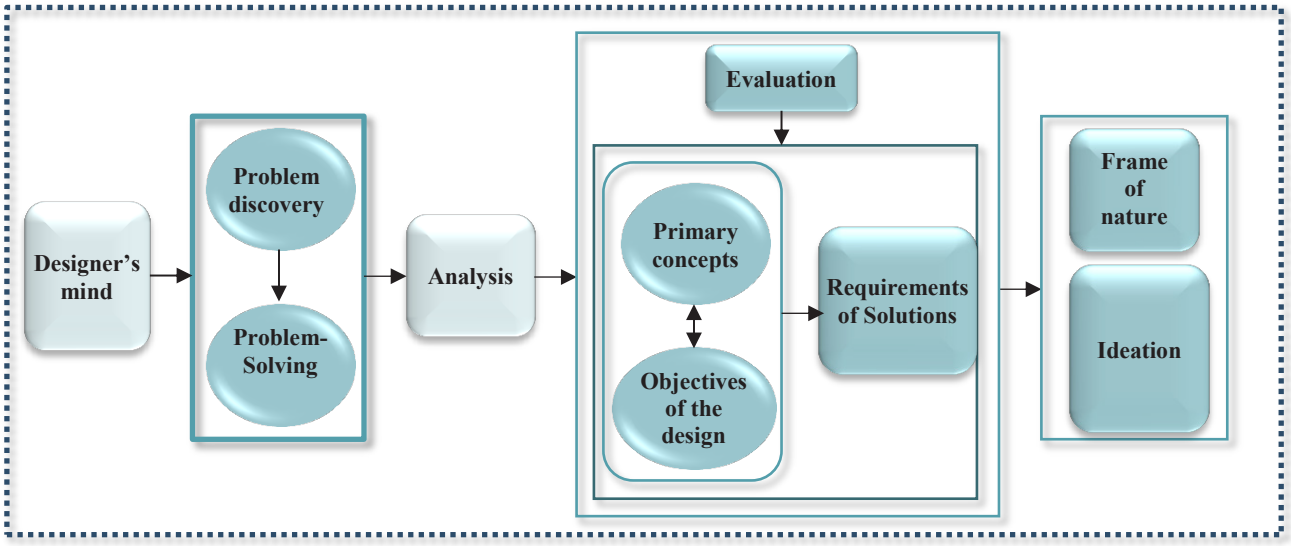

Fig. 4. Stages of finding and solving a problem in the designer's mind. Source: authors.

as the first stage of designing. Basic ideas are the reflection of thoughts and concepts that are formed in the mind of the designer while designing a problem and help him with thinking (Goldshmidt, 1991). Early ideas playing a strategic role in the development of creative solutions. Though they are often vague, they shape the overall approach of designers (Kotsopoulos, 2007; Sharif & Nadimi, 2013).

In the design thinking process, the stages of problem definition, understanding, synthesis, analysis and selection are suggested to the designer. Another important stage that plays an important role in this process is the primary generator, which is often overlooked (Amini et al., 2019). This stage is complex and ambiguous for architectural design learners.

The idea generation and primary generator in the architectural design process are creative stages. The role of primary generators in the formation and maturity of the design is important. Therefore, ideation or problem-solving in the process of architectural design includes understanding and description, development, analysis and organization of problem aspects, discovery and synthesis and aggregation of solutions. This mental process is influenced by the creative thinking of the designer and contributes to the conceptualization[4] of ideas (Mahmoodi, 2001). The process of architectural design is based on creative thinking. To benefit from this thinking in the problem discovery phase, we need to promote ideation and the initiation of design.

- **Bionics and its process**

Adaptation of the forms and phenomena of nature is not a new concept. The use of natural forms and mechanisms has been the primary source of creativity and innovation since ancient times. The practice of construction is as old as human civilization. The structures in nature have long been a source of inspiration and in the present era, the study of natural innovations have led to the creation of a scientific discipline called bionics. Bionics means "biology" or the use of "artificial and physiological organs of nature" and "learning from nature to design technology" or "understanding nature with the help of technology" (Gruber, 2011). Bionics is one of the fields outside of architecture that contributes to architectural creativity (Nari Ghomi, 2018), which is possible through observation, research, analysis and synthesis and does not simply seek to promote copying. This science is based on the hypothesis

that any model can potentially provide ideas for the design of methods and mechanical components and this would lead to the improvement of existing cases (Senosiain Aguilar, 2010). Expecting a biological system to be translated into an architectural system is not justified. Rather, an architect takes, in some respects, fundamental ideas from nature and applies them but he has to modify some aspects of the biotechnology process (Pohl & Nachtigall, 2015) Different aspects of nature can serve as creative tools in the process of inventing design solutions (Tayyah et al., 2021). The goal of bionics is to use nature to inspire researchers in various fields and help them answer their technical questions. In architecture, it also plays the role in ideation (Nari Ghomi, 2018). Nature, with its fifteen basic qualities[5] , can be a good source of inspiration for ideation in architectural design and foster creativity. As Alexander (1964) puts it, in learning how to create a living structure in architecture, it is better to start by looking at nature. Wright also believes that the best source for studying architecture is nature and is the ultimate model for all designs (ibid.). Therefore, it is the inspiration and ideation of nature that adheres to creativity (Fig. 5 & Table 4).

Inferential findings

Based on what has been discussed, we made inferences and attempted to establish the relationship between the propositions.

- **Visual descriptors**

Visual descriptors are a special cognitive strategy in the architectural design process. The reason is that visual retrievals can lead to the creation of the visual and spatial ideas desired by designers. The visual retrievals born during the incubation plays an important role in the architectural design process. According to scholars, the architects' imaginations are the product of images they have seen in the past. As Brown points out, images can reflect the functional and emotional aspects of an idea (Faridizad, 2016). Using an image at the beginning of the design process makes designing much easier compared to the time when the mind is blank (Ashraf Ganjouei et al. 2017). According to research, architectural designers, especially novice learners see visual resources as a source of inspiration and use them in the ideation process (Feyzi & Alipour, 2017). When it comes to enhancing the creativity of novice designers, researchers argue that visual stimuli be more desirable than their absence. Experimental research on designers has shown that

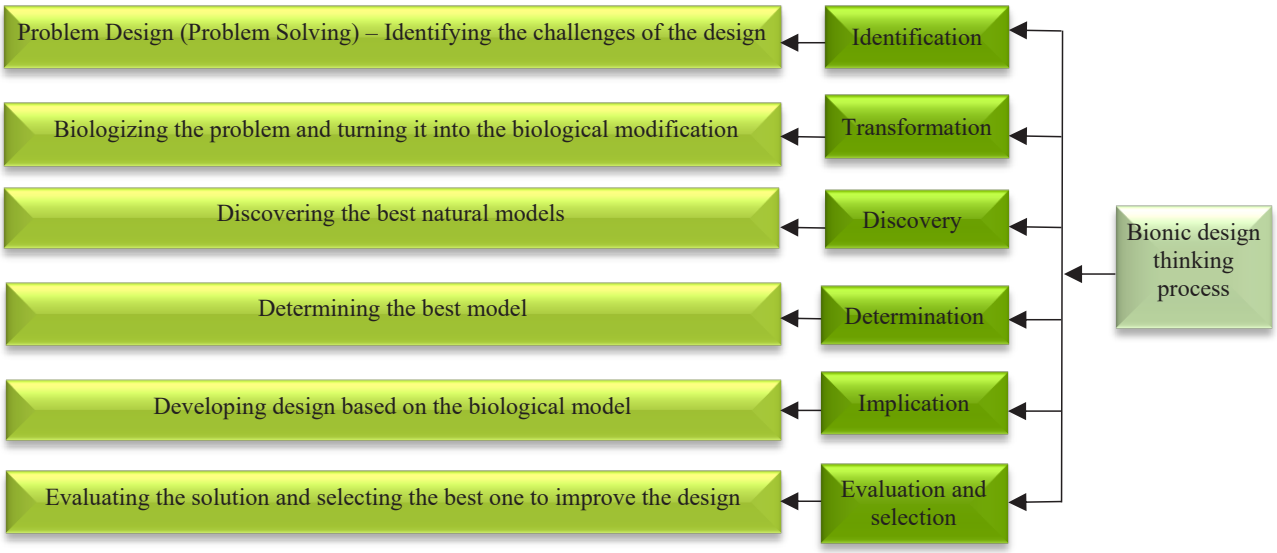

Fig. 5. Bionic design thinking process. Source: authors.

Table 4. Theories of architectural scholars in relation to nature inspiration (bionic). Source: authors.

Source	Theory	Scholars
Golabchi & Khorsandniko (2014)	Systems science is the foundation of all living systems.	Steele (1960)
Gruber (2011)	Systematic implementation and use of technology associated with structures, processes and principles of development in biological systems. This includes various forms, interactions between elements and systems and living and non-living systems.	Nachtigall (1998)
Mahmoudinezhad (2016)	Over the years, nature has updated itself and created forms and systems which can be accessed through technology. Nature can be a good lesson for architects.	Vakulenko (2005)
	Bionics is learning from nature to create independent technical solutions.	Drago (2007)
	The impetus behind using nature as a teacher is to make effective designs that are in harmony with life; being inspired by our natural world to optimize designs.	Kirk (2008)
Mansoorian (2009)	The science of studying models of nature and developing nature-inspired solutions to address human problems	Benyus (1970)
Senosiain Aguilar (2010)	Bionics is interested in creating the functions and forms of living organs.	Senosiain Aguilar (2010)
Ghiabaklou (2013)	Applying the techniques and structures of living things in engineering and designing to solve human problems.	Ghiabaklou (2013)

they begin to come up with ideas using visual stimuli (ibid.). Due to their lack of experience, students and novice designers do not have proper mental images compared to experienced counterparts. Therefore, appropriate objective images with visual stimuli are likely to promote their creativity in generating ideas. Nature can trigger visual images in the minds of designers and help them produce novice ideas. Due to its capabilities, nature can be a good case for observation. By observing nature, learners can discover similarities, associate meanings related to designs and interpret their experience and learning.

- **Variety of solutions - a better understanding of the problem**

Finding different ways to learn about an event helps us to have a better understanding of it. It seems that providing novice designers with an experience would open up an opportunity for them to use all their senses and internalize those experiences. It is believed that the hierarchy of natural phenomena, which include inanimate natural structures, plant, animal and human structures (Sharghi & Ghanbaran, 2012) can serve as a good platform to approach different events from different perspectives and getting to know them better. Because of instability in today's world, the best source for inspiration and ideation are the structures of nature and science, whose stability for many years shows they are effective. The science of nature presents us with empirical methods, structures and systems. Due to its many capabilities, nature can create a better opportunity to understand the problem of architecture. It will be effective in increasing the creativity of novice designers and architecture students. In designing nature-inspired architecture, different aspects of nature can be used. This modeling can be one of the most important methods of fostering creativity and problem-solving in the process of architectural design. nature can serve as a guide to creativity.

- **Bionic creativity in the architectural design process**

Bionic architectural solutions contribute to the

creativity of novice designers by combining "revelatory creativity" with "creative thinking". Creative thinking is finding solutions to existing challenges based on the pattern and models provided by nature. modeling can be categorized as follows:

1. Visual modeling (it is a shallow and imitative method that does not pay attention to the principles and foundations of structure) (Mahmoudinezhad, 2016);
2. Conceptual or metaphorical modeling (the abstract perception that is far from superficiality);
3. Computational Modeling;
4. Modeling the laws of nature;
5. Analogy (comparing and contrasting, finding similarities, discovering implicit meaning, establishing an equilibrium in performance and behavior) (Gruber, 2011).

According to McGinty, design ideas are divided into five groups: deductive, quintessential, metaphorical, problem-solving and organic. In this classification, "deductive" and "metaphorical" ideas are the topics triggering creativity by nature. The deductive idea is the result of understanding and finding the similarities of the design problem with the source of the idea and discovering the objective relationship between them. These ideas spark in the mind of the designer during the design process. The "metaphorical idea" refers to new interpretations of the design problem using imagination. This is beyond analogy and is manifested in the world of meanings and the stage of inspiration. Therefore, in designing the nature-inspired architecture (bionic architecture), it is possible to have all kinds of perceptions (i.e. superficial, structural, metaphorical and copying) (cited in Feyzi & Alipour, 2017). But based on what has been discussed it seems that the structural and metaphorical use of images (nature frames) as a visual stimulus can effectively promote creativity in the design process.

• The process of the correspondence and transformation of bionic to the design problem

Fig. 6 shows the extent to which the bionic stages correspond to the design problem. Osborn (1953) argues that the process of architectural design and creativity (the bionic creative design process) is not in contrast with the formulation of this process. He maintains that modeling this process is neither scientific nor practical, it can only serve as a roadmap for creative problem-solving architectural design.

Conclusion

Previous research has emphasized the necessity of using nature in architecture. However, the studies have not shown how a designer can learn from nature in the design process to produce a creative architectural design product. This research seeks to understand how bionic science contributes to the creativity of new students during the process of architectural design. The impetus behind this study is to take advantage of nature during this process to enhance the creativity of new students. The present study argues that asking students to strictly follow the rules of a particular method will restrict the mental freedom of novice learners. This highlights the necessity of working on a process that will guide us to reach this goal. In-depth knowledge of the design process will help novice architectural students to have the method and timing guidelines in their minds.

Analyzing and aggregating 100 pertinent references and examining the above- mentioned diagrams show that architectural design includes the following stages: A) problem discovery B) problem-solving, C) analysis, D) synthesis and, E) evaluation. The creative process steps include A) initial perception, B) problem framing, C) preparation D) incubation, E) enlightenment, F) illumination, G) negation and H) proof. These stages overlap each other at some point. This indicates that creativity is a necessary but latent part of the design process reflect architectural design in the architect's mind (See Figs. 5 & 7) and in response to the first question of the research, it can be stated that the first stage of creativity in the process of architectural design is the identification and clarification of the problem

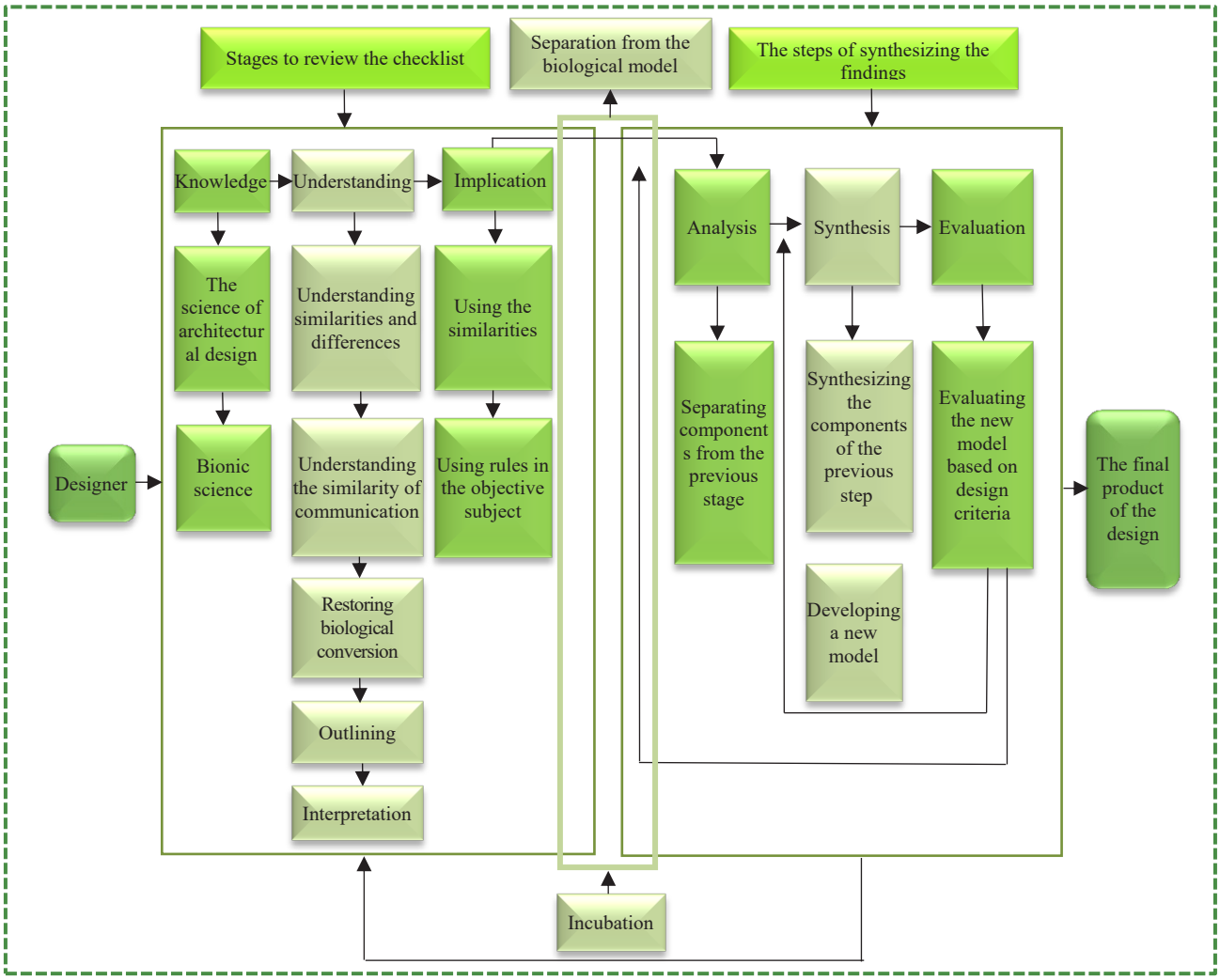

Fig. 6. The process of the correspondence and transformation of bionic to the design problem. Source: authors.

by framing it. Therefore, creativity can integrate into the process when the problem has been discovered and clarified. In line with the findings of research studies, it can be stated that designing ideas are not created out of anything, but are derived from previous ideas, it seems that problem framing, which is one of the early and common stages of the design and creativity process, can be informed by nature (i.e. bionics).

There is always an evolutionary process in nature that eliminates inefficiencies and these inspiring patterns can substantially improve the design process of novice architectural learners. Understanding the problem is an important initial step to use nature as a model. Then, the checklist[6] and the extent to which this list matches the design problem (rating scale[7]) needs to be considered (See Fig. 6). However, having an effective conceptual image and a valuable visual stimulus in nature will not lead to creativity. Insisting on nature-inspired ideation is the necessity of fostering creativity. Using nature as a specific and perfect pattern for architecture would result in generous different concepts, solutions and potential realities. All these facilitate achieving a creative architectural design.

In moving from known propositions in nature to an unknown proposition in architecture, one must use the correct information based on the design

problem in the checklist and after extracting these propositions, the components need to be properly put together and combined. This will lead to a variety in the final design inspired by nature in the creation stage. This study explains how the correspondence and transformation of bionic to the design problem can be carried out and propose the creative process model of bionic architecture design in (Figs. 6 & 7). Given that nature has been referred to as a natural selection over years, integrating innovative patterns in the creative solution of design problems is not easy. This requires an in-depth study of the underlying criteria. Future studies can test the model proposed (See Fig. 7) based on the results of this study. A qualitative study can be carried out on first-year students of architecture to examine the effect of natural visual richness on creativity. It is recommended that scientific propositions should also be examined through empirical methods.

Endnote

1. Framing is a special concept according to which people interpret different procedures. Our interpretation of the world depends on our point of view and the lens and frames through which we look at the world. Framing is a strategic issue in the face of a design issue that has a special place in the design process.
2. When a designer is faced with a problem, he has a unique perception and interpretation of the problem, its components and relationships. Such a perception is like a filter, glasses and lens through which the designer looks at the problem. This is called a "frame".
3. In different sources, the term idea has been interchangeably used with the theme, image, raw or footnote design, initial bold, regulating principle and idea, conjecture or frame of the problem.
4. The concept refers to the idea that leads to the design.
5. The fifteen features of nature that Christopher Alexander mentions include the following: 1- Level of scale, 2- Strong centers, 3- Boundaries, 4- Gradients, 5- Contrast, 6- Intermittent repetition, 7- Deep coherence and ambiguity, 8- Good shape, 9- Roughness, 10- Echoes, 11- Positive space, 12- Void space, 13- Simplicity and inner peace, 14- Non-separateness, 15- Local symmetries.
6. It refers to a list of things representing the problem of architectural design in nature, which includes behaviors, features, structure, body,

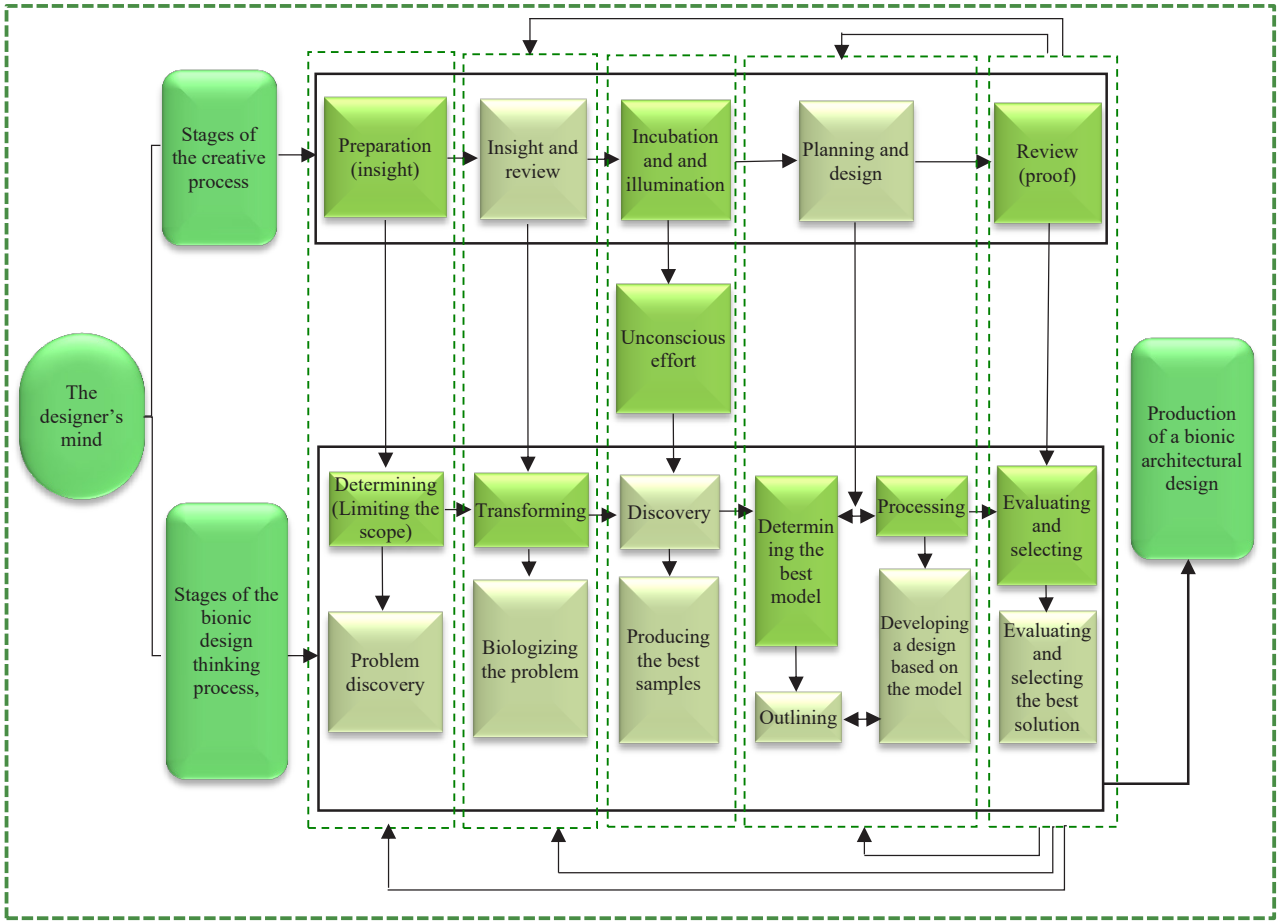

Fig. 7. A proposed model of the creative process of designing bionic architecture. Source: authors.

materials and textures, etc., They are occurring during the preparation stage and framing of the problem. The designer's mind creates the framework for the emergence of creativity based on biological studies and education. This step takes place after the creative discovery of the design problem and is a reversible step.

7. This step, which includes examining the characteristics, consequences and main objectives. First, the properties of the biological samples should be examined according to the design problem, then the designers need to consciously choose a checklist. Finally, he considers the subconscious purposes of using the sample. Then rates the extent to which the design problem corresponds the function, form, texture, structure, color, materials and structure of the sample on the checklist.

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