Available online at www.ijapas.ir

International Journal of Applied Arts Studies

IJAPAS 7(3) (2022) 07–22

Nature Inspired Strategies as a Sustainable Problem-Solving Methodology in Architecture Design Process

Shermin Olia[a], Farah Habib[b]*, Azadeh Shahcheraghi[c]

[a]*Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran*
[b]*Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran*
[c]*Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran*

Received 28 August 2022; accepted 16 December 2022

Research Article

Abstract

Utilizing natural tactics has a huge impact on the design of developing environments that are environmentally friendly. The review of relevant scientific research, the intricacy of biological issues, and their application to the architectural field are all challenging and time-consuming tasks that also need knowledge in the biological sector. The use of nature's strategies in architectural design is hampered by a lack of adequate information and the right comprehension, which also results in improper application and the appearance of impediments. To use the strategies derived from nature in the field of architecture, the right attitude, method, and tools should be identified to translate the strategies into architectural solutions. This is because the main objective of the current research is to extract the missing link bridging the biological and architectural domains. By discovering, the method of creating a connection and link between the biological domain and architecture through mixed methods Research. The research was carried out utilizing various

* Corresponding author. Farah Habib.
E-mail address: frb_habib@yahoo.com

This article is adapted from Shermin Olia's Ph.D. thesis entitled "Explaining the Conceptual Model of the Architectural Process Method Inspired by Nature" supervised by Prof. Farah Habib and advised by Dr. Azadeh Shahcheraghi in Science and Research Branch, Islamic Azad University.

The authors appreciate the students of the course "Human Nature Architecture" for the Bachelor's Degree in Architecture for the academic year 2019-2021 of the Islamic Azad University Science and Research Branch of Tehran and the Islamic Azad University of Mashhad regarding their participation in the Focus groups research. Furthermore, we would like to extend our sincere gratitude to Dr. Niloufar Zounemat Kermani, a second researcher, for her insightful advice and assistance with data gathering during the development of this research project. Her willingness to that so kindly donated her time has been much appreciated.

quantitative and qualitative methods in three key sections. Step 1: Theoretical analysis to identify and classify the key elements of natural strategies as well as their effects. Step 2: Using logical reasoning and a case study to determine the attitude, method, and tools of data transmission and to develop an architectural solution. Step 3: Focus groups (Participant Observation) to test the defined Process of Creating Architecture Using the Nature Design Strategies Hypothesis. For employing nature design methodologies in the realm of architecture, two problem-solving attitudes the problem-based attitude and the solution-based attitude were identified. Based on these two mindsets, a four-phased process was described for using natural strategies in the design process. Tools and measures that were required for each phase were determined and discussed. Two diagrams were provided at the end.

Keywords: Nature Inspired Strategy; Sustainable; Problem-Solving Methodology; Architecture; Design Process

1. Introduction

Throughout history, many designers have been inspired by nature to design and create new forms and have sought to find advanced technical solutions based on nature design strategies. In the field of sustainable human-made environment development, natural patterns such as trees or bone structures have been a source of inspiration for the development of some architectural materials and elements (Mattheck and Burkhardt 1990; Harman 2013). We can be inspired by how organisms solve problems and their evolved adaptation process. This method can be used in the process of designing and reaching creative ideas (Langrish 2004). Designers and architects can benefit from developing nature's self-made approach and using the resulting knowledge to achieve sustainable societies and systems. According to the findings of the Biomimicry Institute, the more the function of the human-made environment resembles the natural world, the more likely it is to survive, and this is a special concept of sustainability. In the field of practical completion and implementation of sustainability in design and construction, a balance should be established between economic, environmental, and social aspects in production and service provision (Charter and Tischner 2001). The potential role of designers in achieving sustainability and their contribution to creating a sustainable world has long been recognized (Ehrenfeld 2008; Manzini 2009; Margolin 1998; Papanek 1971; Rahimifard and Clegg 2008). Several sources have investigated and studied how design derived from nature can work in line with the well-known concepts of "sustainable development" (Bakker et al. 2009; Brezet and van Hemel 1997; Dewberry 1996; Hallstedt 2008).

Nature has created complex mechanisms and methods for survival. By knowing and learning from nature in solving design and architecture problems, we can achieve new technologies in different fields to solve them. It should be noted that life and nature are not separate from each other and man is also a part of it, as a result, the obstacles and components that separate man and nature should be identified, and by examining and understanding their function in Nature should use them as a tool to solve human problems (Baumeister 2011). As an architect, one can be inspired by nature and learn how organisms adapt to nature to implement their strategies in architectural processes (Weinstock 2008). Architecture and nature have common features because both have the same logic of growth and adaptation. However, most designers translate the form found in nature with building materials into geometric shapes only, without understanding the structure and logic behind the materials and components (Oxman 2010). As a result, there is a gap between finding formal and physical methods related to nature that most designers have extracted from nature.

While they should have learned from nature with a correct understanding of biological systems. The relationship between materials and their formation processes, which is important in form production, should not be ignored. To fill the gap between the relationships of materials, the material processes formation, and its effect on form, new technologies change the way of designing in architecture. This is achieved by using the behavior of living organisms in the process and studying the laws and logic of nature (El-Mahdy and Gabr, 2017).

The evaluation of current scientific publications in this sector, as well as the transfer of biological issues to the architectural domain, is a challenging and time-consuming operation that frequently necessitates the competence of the biological area. The employment of nature's design strategies in the domain of architectural creation is hampered by a lack of enough information and the right comprehension, which also results in improper application and the appearance of impediments. What are the attitudes, tools, and procedures for translating nature-inspired design strategies to the architectural domain and using them in architectural creation? Is the issue this paper aims to address? It has also been discovered that nature effectively inspires design methodology in the creation of architecture. The following are the research's objectives in this regard:1. Investigating how nature's strategies affect and apply to the field of architecture (tools and methods); 2. Examining the type of attitude and method designers take when applying nature's strategies to the architectural domain (transferring the strategies of nature to architecture). A Mixed Methods study using Theoretical Analysis, Logical Argumentation, Case Study, and Focus Groups (Participant Observation) has been utilized to discover how methods and tools connect the biological domain and architecture area. The major aims of this research are to describe the process of architectural design influenced by natural design strategies and to find the missing link between the biological domain and the architectural domain.

2. Material and Methodology

2.1. Research Methodology

The nature design strategies have different dimensions and levels. The most indispensable dimensions parameters of the nature strategies are the characteristic of the organism, social relations of the organism, and Ecological relations of the organism, which are examined at different organism levels, which include form, materials, structure, process, and function (Zari et al. 2007).

To use nature-inspired design strategies in the architectural field, the right attitude, method, and tools must be identified. This will allow the strategies to be converted into architectural solutions. The primary objective of the research is to identify the missing link between the biological field and the architectural field. Extensive theoretical analysis was first carried out to determine the attitude, approach, and tools of utilizing nature's tactics in building (Fig 1).

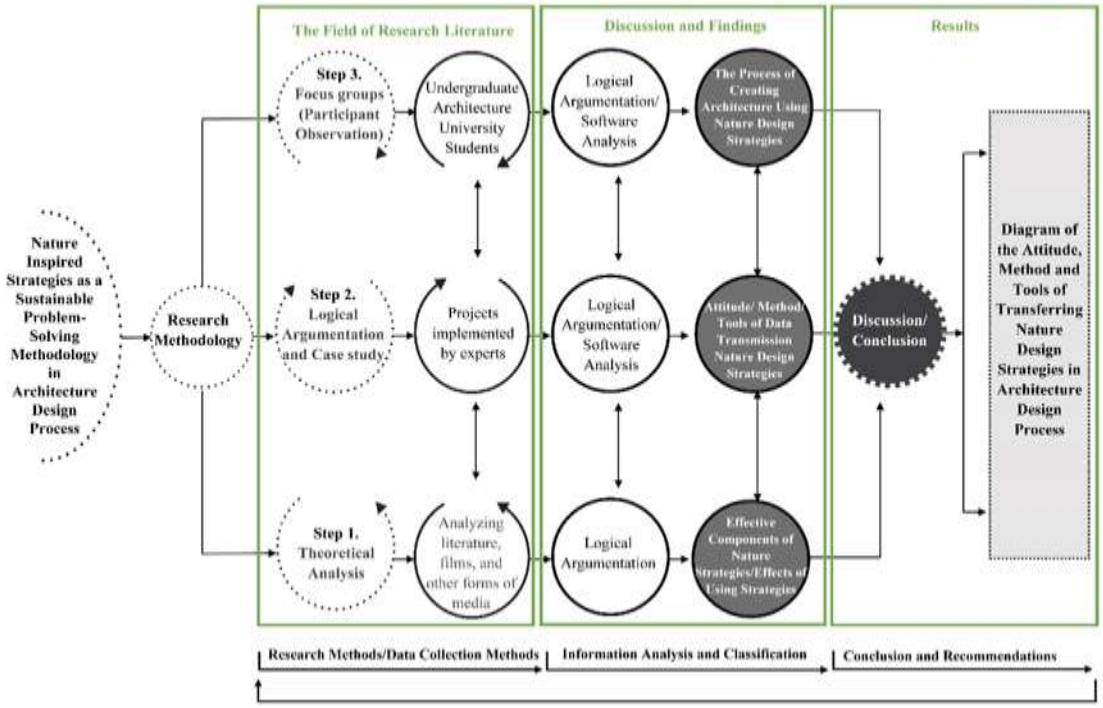


Fig 1 Research Methodology diagram

At this point, the methods already in use in the field of design with the intention of sustainability were categorized. Then, three design approaches were chosen by specifying three filters (as indicated in Section 3.1). The control strategy was also determined to be the canvas design approach. Eco-design is a more well-known method than the other two, cradle-to-cradle and Hanover principles, which is why it was selected as the control strategy. The bases and guiding concepts of the four approaches were then extracted, categorized, and described, along with the design methodology. The design process was thereafter identified and classified by specialists in the field through the use of documentary studies in the following stage. The design process and the default test of the outlined design process were achieved in the following through Logical Argumentation and Case study. In this sense, the projects of the specialists in each approach were chosen, and the attitude, method, and tools employed by the project architects and their design team were determined by reviewing the documentation that was already in place as well as the visual reports of the projects. The model that was presented as the research's final finding was then explained. To test this model, focus groups (participant observation) were held among the statistical population of the "Human Nature Architecture" course students at Islamic Azad University's Mashhad Branch and Science and Research Branch (Table 1). In three successive academic semesters, 132 students were included in the statistical population. A pre-test has been carried out to guarantee the reliability and validity of the tests created by the researcher. The second researcher was requested to work together with the first to enhance the effectiveness of focus groups (participant observation).

It is possible to acknowledge the following when describing the rationale behind selecting the course "Human Nature Architecture" for this study: the course "Human Nature Architecture" is presented in the third semester, and at this time, the architectural character and general principles of the student's design have not yet been formed. By passing the "Architectural Design Preliminaries

1" course, which is a prerequisite for the "Human Nature of Architecture" course, students have gained knowledge of the fundamental concepts and basics of design.

Table 1 Focus groups (Participant Observation) on 132 students in two stages of pre-test/ test in 2019-2021

Gathering information of the architecture creating process inspired by nature			
Final project: Designing the smallest residential unit for an architecture student with a certain approach.	**Focus groups (Participant Observation)**		
	Pre-test	**Test**	
Approach	Second semester Islamic Azad University of Mashhad 9 groups	First semester Islamic Azad University of Mashhad 24 groups	Second semester Islamic Azad University Science and Research Branch 24 groups
The Hannover Principle (HP)	3 groups (n= 4)	6 groups (n= 2)	6 groups (n= 2)
Biomimicry (Bio)	3 groups (n= 4)	6 groups (n= 2)	6 groups (n= 2)
Eco-design (Eco)	3 groups (n= 4)	6 groups (n= 2)	6 groups (n= 2)
Cradle to Cradle	-	6 groups (n= 2)	6 groups (n= 2)

The nature design methodologies have been organized, contrasted, and examined in the designed tests in the form of workshops and student design projects. The amount of knowledge and implementation of the strategies, the kind of selection, the quality of results, and the students' emphasis on topics are all taken into consideration when comparing different selection strategies. The statistical population of this study was chosen based on the evolutional sampling method in nine groups of four students for the pre-test of the course "Human Nature Architecture" for the bachelor's degree in architecture for the academic year 2019–2020 of the Islamic Azad University of Mashhad branch. Students from the Islamic Azad University science and research branch and the branch in Mashhad that offers the bachelor's degree in architecture for the academic year 2020–2021 participated in the test by studying the course "Human Nature Architecture" (Table 2 and 3). The student's final project, which they completed and presented in groups of two, was evaluated and graded as a poster that included a thorough explanation of the design. Two visiting professors and a second researcher who was completely knowledgeable about the topic and the work method attended the final meeting and student project evaluation. Additionally, the researchers assessed and dissected the full report of the student's work and design that was provided in book form (design work report book). The design work report book contains studies, etudes, a description of the concept, and instructions for how to complete the project. The student explained each area. What motivated him and how did he arrive at the project's concept based on the nature-inspired design strategy selected approaches?

3. Theory

3.1. Nature-Inspired Design Strategies Selection

To achieve sustainable solutions, nature can be used as a mentor and reference. Therefore, we define the term "Nature inspired design strategies" as a general term or definition: "Nature-inspired design strategies" are strategies that are based on "learning from nature" and consider nature as a sustainable paradigm. The current research started with the analysis of specific strategies of sustainable design to achieve the attitude, method, and tools of using "Nature design strategies" in the process of creating architecture, which offers opportunities to design differently and sustainably. They have a significant impact on the design and intellectual apparatus of designers. Because of the inspiring results of using these strategies, some refer to this period as the "third

green wave" (AIGA 2010; Bakker et al. 2009; de Pauw 2015). In analyzing these strategies, we found the common feature of "learning from nature". To determine which strategies should be selected for the research project, we analyzed a comprehensive list of sustainable design strategies provided by AIGA. This list of thirty sustainable design strategies includes "main sustainability visions, manifestos, frameworks and tools that have been used over the past fifty years" (Brink, Destandau, and Hamlett 2009; de Pauw et al. 2010).

Our main goal was to select those that can be introduced as "Nature inspired design strategies in architecture creation", in this regard, based on the objectives of the research, we defined three criteria that were applied as a filter for selecting strategies, and based on that, strategies was investigated and defined. Filters have been applied to select strategies as follows: Filter one: Makes Reference to Nature. The question raised in this filter is: Does the strategy explicitly refer to nature? Filter two: Inspiring by Nature in the Design Process. The question raised in filter two is: Which of the selected strategies in filter one has used nature in the design process? This means that after identifying the traces of the use of nature in filter one, in which of the strategies has nature been used as a source of design inspiration, design principles, tools or design goals, or design methods? Filter three: Use Nature in the Creation of Architecture. The question raised in filter three is: In which of the strategies has nature been used as a source of inspiration in creating a form/process or system in the process of creating architecture? (Fig 2)

- ***The results of Filter 1:*** Among the thirty strategies classified by the AIGA Research Institute, six strategies "Makes Reference to Nature" which are: The Hanover principles, IDSA Eco-Design Principles and Practices, The Natural Step, Biomimicry, Natural Capitalism and Cradle to cradle.

- ***The results of Filter 2:*** According to how "nature" is used in the six strategies selected from filter one, two different methods were identified: a) strategies that model nature directly in the design process and b) strategies that use nature to They have modeled indirectly in the design process. Four of the six Hanover Principles, Biomimicry and Cradle to cradle use nature directly as a source of inspiration, principles, tools, goals, and methods for design. In the book "Biomimicry: Innovation Inspired by Nature", Janine Benyus (2002) suggests using nature as a mentor and source of inspiration by changing the way of thinking about innovation. The Cradle to Cradle strategy has defined the concept of environmental effectiveness. Nature works based on a system of metabolism and food. There is no such thing as waste, and the ability of materials to revive and live again is used, which means that the waste of one system becomes food for another system. In the design process, it means that: the design is done in such a way that the components can be separated so that they can be easily decomposed in nature, or those components can be used in making another product (McDonough and Braungart 2002). On the other hand, the other two strategies have the principles and methods of concern for protection and interaction with nature.

IDSA Eco-Design Principles and Practices express two principles by indirectly using nature, they are: 1. The continuation of the life of humanity and the planet are dependent on each other; 2. The planet can survive without the presence of humans, but the continuation of human life depends on the health of the planet. In The Natural Step strategy, nature is used to determine "system conditions" and "sustainability principles". This strategy focuses on factors that should not be done in nature to achieve sustainability.

- ***The results of the third filter:*** the last filter in the selection of strategies is based on their application in the creation of architecture. After the studies based on the defined filters Hanover principles, Biomimicry, and Cradle to cradle are strategies that have used nature as a source of inspiration in the creation of architecture.

In short, Hanover principles, Biomimicry, and Cradle cradle have been chosen for a current research project. To obtain and extract the features of distinction and similarity of the use of these approaches, a comparative study was conducted, in which the effects of using the three strategies were compared to Eco-design, which is a well-known strategy in the process of designing sustainable architecture. Analysis was done. Eco-design strategy is a strategy that is known as "the integration of environmental considerations in design" and therefore it can be considered the basic strategy related to environmental sustainability in the design process with a history of 40 years (Stevels, 2001; van Hemel and Cramer 2002). To describe its use as a basic strategy in design, a more precise definition was provided, which is: "Eco-design is a strategy in which the complete life cycle of a product is considered and environmental aspects are taken into account at all stages of the design process. Moreover, create the least environmental impact during the life cycle of the product.

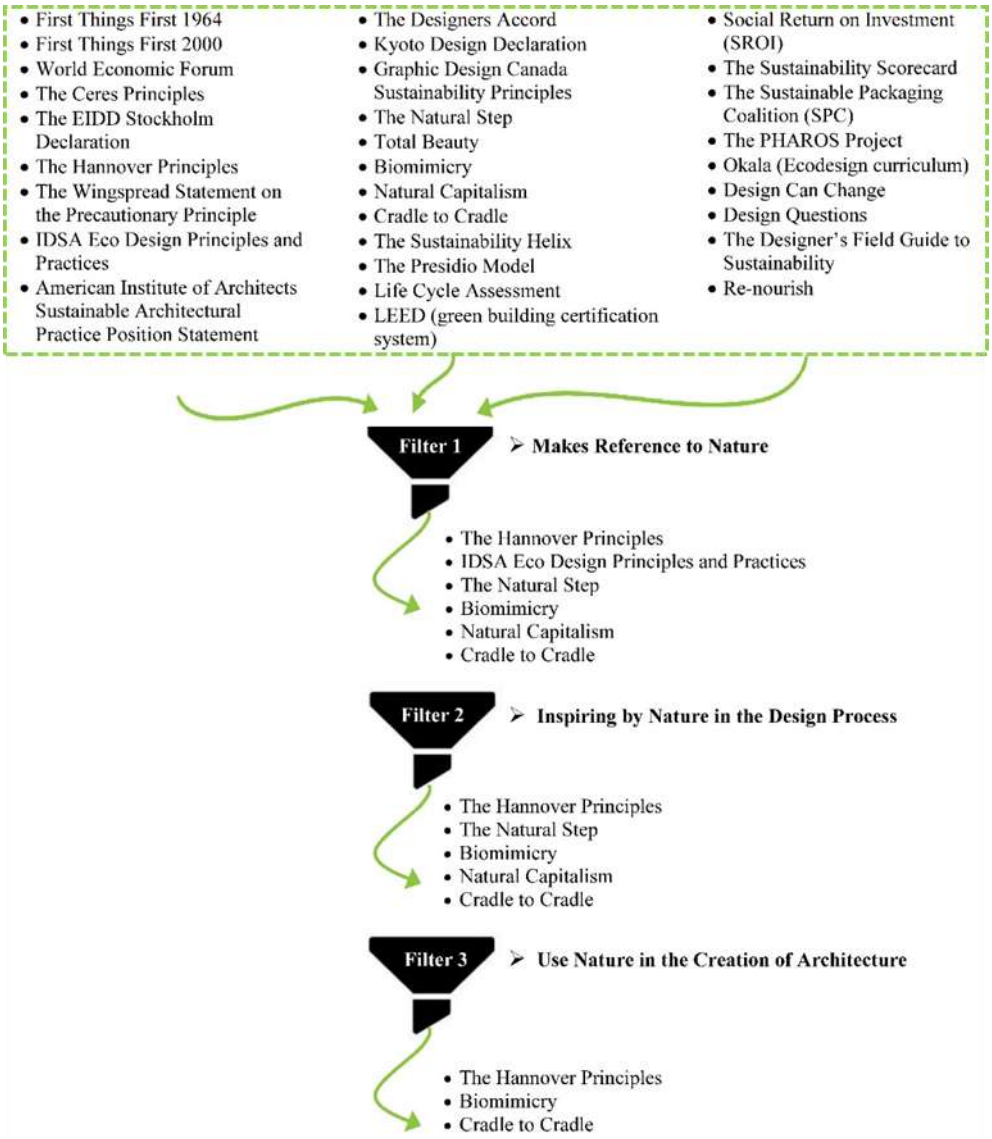


Fig 2 Sustainable design strategies and their classification based on the use of nature strategies in the creation of architecture (Based on Brink; Destandau and Hamlett 2009; de Pauw 2015)

3.2. Problem Solving Approaches

Approaches to nature-inspired strategies as a design process can be followed into two categories as Problem-based approach (Top-Down Approach) and Solution-based approach (Bottom-Up Approach). Although Top-Down (Problem-based) approach has different naming, all refer to the same meaning. Such as the "Top-Down Approach" (Kinppers, 2009); "Problem –Driven Biologically Inspired design" Michael Helms Swaroop and his colleagues at Georgia Institute of Technology defined the Top-Down approach within six nonlinear and dynamic levels, each output influences previous phases and provides refinement loops (Helms, Vattam and Goel, 2009) (Fig 3a).

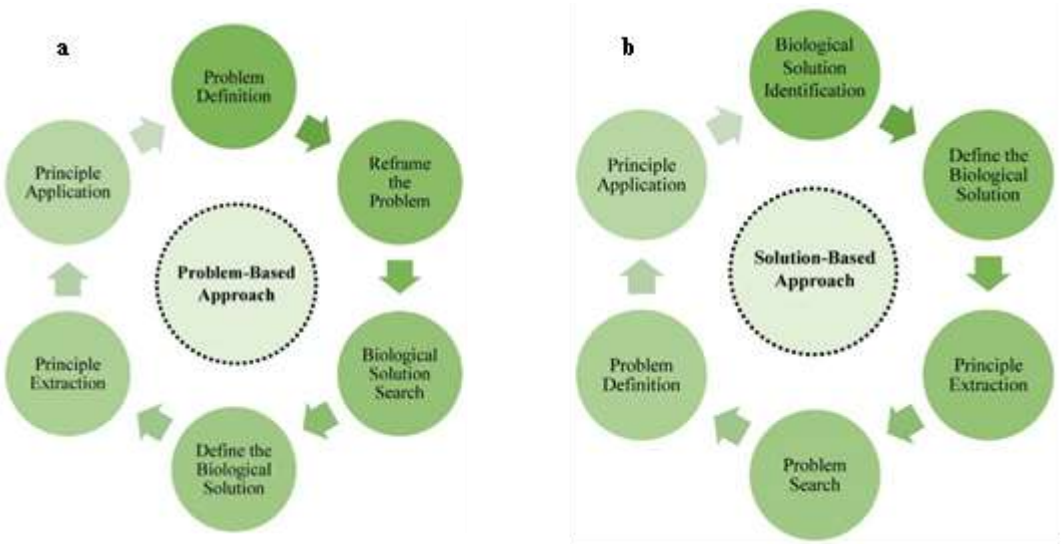


Fig 3 a Levels of the Top-Down (Problem-Based approach) approach, **b** Levels of Bottom-Up (Solution-based) approach

Zari named it "Design looking to biology"; Nature is full of solutions for human problems that designers can identify and learn from, and with help of biologists, designers can apply and match their problems with organisms, which salved the same issues (Zari, 2007). In the Bottom-Up (Solution-based) Approach, biology influences design in the sense that the source of inspiration and natural strategy is first identified and fully explored at different biological levels; In such a way that it can be properly used as the foundation of the design. In this approach, the design depends more on biological and ecological knowledge than on human problems (Vincent, Bogatyreva, and Bowyer, 2005) Michael Helms Swaroop and his colleagues at Georgia Institute of Technology defined the Bottom-Up approach within seven levels (Fig 3b) (Helms, Vattam and Goel, 2009).

4. Exploring the Application of Selected Strategies

The study design books of the students' design groups were examined to analyze the use degree of nature-inspired design strategies in each group according to their attitude toward solving the design problem, methods, and tools, were analyzed and explained. This was done to achieve the research's objectives (Fig 4).

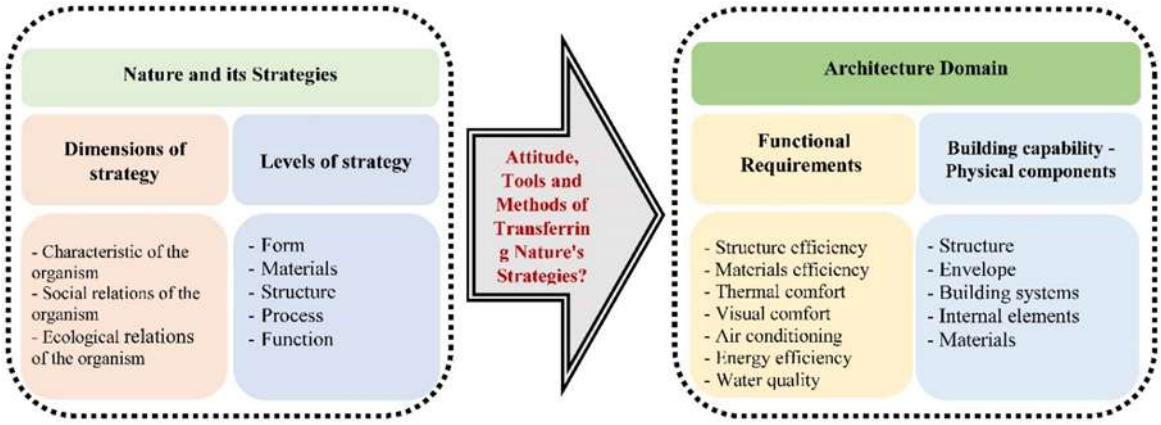


Fig 4 Transferring nature design strategies to the architectural domain

In this manner, a table with the dimensions and levels of the nature strategies and the assessment of the degree to which students successfully used and converted the natural strategies into architectural solutions was created. While the students were presenting their work, this table was prepared with the researcher's active participation and with the second researcher's invitation. Documents and design books belonging to the students were also examined.

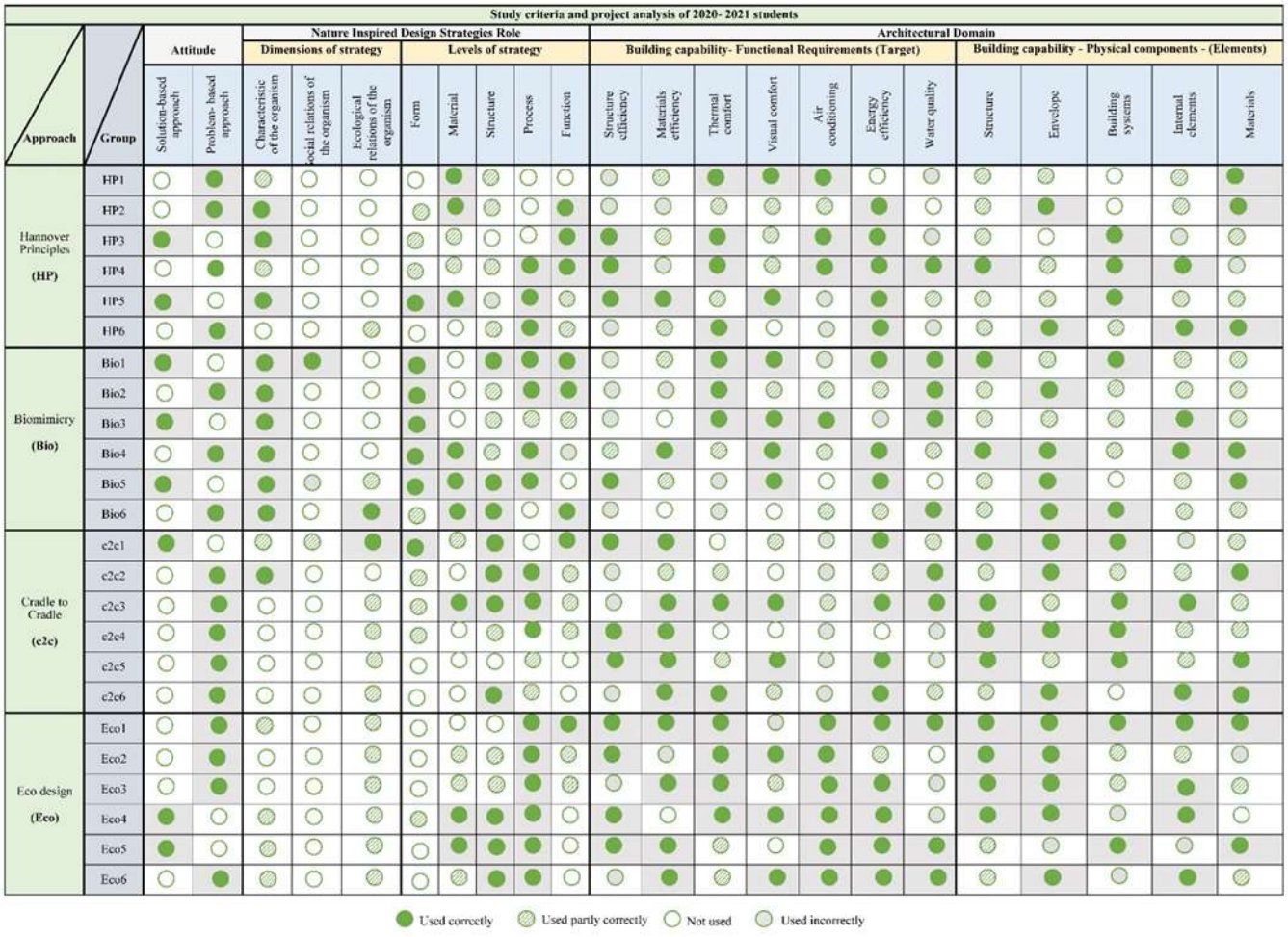
The characteristics of the organism, the social relations of the organism, and the ecological interactions of the organism are the most crucial dimensions parameters, and they are studied at many levels in nature-inspired design methods with various dimensions and levels. These levels are function, form, materials, and structure. Finding and extracting architectural solutions depends on the study of the aforementioned dimensions and levels, employing the appropriate tools to comprehend, extract, and implement these answers, and translating knowledge from the biological world to architecture. To fill in the gap between the biological and architectural fields, it is important to understand the mindset, level of focus, methodology, and tools that go into employing nature design strategies in architecture. To find and extract architectural solutions, it is crucial to study the aforementioned dimensions and levels. It is also crucial to use the right tool for understanding, extracting, and applying these solutions. Finally, it is crucial to transfer knowledge from the biological domain to architecture. Extensive field investigations were conducted in this respect to fill in the gap between the biological field and the architectural domain, to learn the attitude, level of concentration, method, and tools of employing nature design strategies in architecture, and the results are presented in Table 2, and 3.

Table 2 Project analysis of 2020- 2021 Islamic Azad University of Mashhad students

Study criteria and project analysis of 2020- 2021 students																							
Approach	Group	Attitude		Nature Inspired Design Strategies Role								Architectural Domain											
				Dimensions of strategy			Levels of strategy					Building capability- Functional Requirements (Target)							Building capability - Physical components - (Elements)				
		Solution-based approach	Problem- based approach	Characteristic of the organism	Social relations of the organism	Ecological relations of the organism	Form	Material	Structure	Process	Function	Structure efficiency	Materials efficiency	Thermal comfort	Visual comfort	Air conditioning	Energy efficiency	Water quality	Structure	Envelope	Building systems	Internal elements	Materials
Hannover Principles (HP)	HP1	○	●	◍	○	○	○	●	◍	○	●	○	◍	●	●	●	◍	◍	○	◍	○	◍	●
	HP2	○	●	●	○	○	●	●	◍	○	◍	◍	○	●	◍	●	◍	○	○	●	○	●	●
	HP3	●	○	●	○	○	○	◍	◍	○	◍	●	◍	●	○	●	●	◍	○	○	●	◍	◍
	HP4	○	●	●	○	○	◍	●	○	●	◍	○	○	●	○	●	●	●	●	◍	●	◍	●
	HP5	●	○	●	○	○	●	●	◍	○	◍	●	●	◍	●	◍	◍	○	○	●	●	○	●
	HP6	○	●	◍	○	○	◍	○	◍	◍	●	●	◍	●	○	◍	●	○	○	◍	◍	○	●
Biomimicry (Bio)	Bio1	○	●	●	◍	○	◍	◍	○	◍	●	○	●	○	○	●	◍	●	○	●	○	◍	◍
	Bio2	○	●	●	○	◍	●	○	◍	◍	●	○	○	●	●	●	●	●	◍	●	●	●	◍
	Bio3	●	○	◍	●	○	◍	○	◍	●	●	●	○	◍	○	○	●	○	●	◍	◍	●	○
	Bio4	●	○	○	◍	●	●	○	◍	●	●	●	○	◍	◍	◍	●	●	○	●	●	○	○
	Bio5	○	●	◍	●	○	◍	○	●	●	◍	●	◍	◍	●	○	●	○	●	●	○	◍	○
	Bio6	●	○	○	◍	●	○	○	●	●	●	○	○	●	◍	◍	●	●	●	◍	●	●	○
Cradle to Cradle (c2c)	c2c1	○	●	○	◍	○	◍	○	◍	◍	●	○	◍	●	◍	○	●	●	○	●	○	◍	●
	c2c2	○	●	◍	○	●	◍	●	◍	◍	●	○	●	○	●	●	●	◍	●	◍	●	○	●
	c2c3	●	○	○	●	◍	◍	○	○	○	●	●	●	◍	◍	○	○	◍	◍	◍	●	●	●
	c2c4	○	●	○	●	◍	◍	○	◍	●	●	◍	●	◍	●	◍	○	○	◍	●	○	●	●
	c2c5	●	○	○	○	◍	◍	○	●	◍	●	○	●	◍	●	○	○	◍	○	◍	●	○	●
	c2c6	○	●	◍	○	●	●	○	◍	○	●	○	○	◍	●	●	○	●	◍	●	◍	●	○
Eco design (Eco)	Eco1	○	●	○	○	◍	◍	◍	●	◍	●	●	◍	●	●	◍	○	○	●	◍	●	○	○
	Eco2	○	●	○	○	●	◍	◍	●	◍	●	●	○	●	◍	●	●	○	●	●	◍	●	○
	Eco3	●	○	○	○	◍	◍	◍	○	○	◍	○	●	◍	●	◍	●	●	○	●	○	◍	●
	Eco4	●	○	○	○	◍	○	○	◍	●	●	◍	●	◍	●	◍	○	●	◍	●	●	●	○
	Eco5	○	●	◍	○	●	○	○	◍	●	●	◍	●	●	●	●	●	●	●	●	◍	●	○
	Eco6	○	●	●	○	◍	◍	◍	◍	●	●	○	◍	●	◍	●	○	○	●	●	◍	●	●

● Used correctly ◍ Used partly correctly ○ Not used ◍ Used incorrectly

Table 3 Project analysis of 2020-2021 students of Islamic Azad University Science and Research Branch



5. Discussion and Conclusion

Nature has long served as a source of inspiration for designers and architects in their work. Different approaches for integrating nature with design, utilizing nature as a tool for problem-solving, and raising the level of compatibility of the design with the environment and its context have been proposed and developed. Initially, simply the copying of the physical shape and appearance of nature was explored, but throughout time, they looked for techniques, tools, and design strategies that were comparable to how plants and animals grow and evolve.

To execute their strategies in architectural processes, architects might draw inspiration from nature and study how organisms adapt to their environments. In this regard, a design project that has been looked into and analyzed utilizing nature-inspired design methodologies is the subject of theoretical analysis, logical argumentation, case study, and holding focus groups (participant observation). Table 2, and 3 have been created after the investigations have been completed by the planned objectives to provide the most simple reading of the findings.

This study set out to clarify the "attitude, method, and tools" associated with applying nature-inspired design strategies to the architectural design process. When using nature design

methodologies, two problem-solving attitudes have been identified: the problem-based approach, also known as the top-down approach, and the solution-based approach, also known as the bottom-up approach. Utilizing both attitudes will benefit the designer in creating a sustainable product. The type of attitude is determined by the type of design problem. The kind of design problem and the requirements it presents will determine the type of problem-solving approach to use. Following the selection of the attitude type, the design process is carried out by the attitude type. Four steps of the procedure were described, one for each attitude. Tools and measures that were required for each phase were determined and modified. At the end of phase three, the validation procedure is also recognized and described.

Researchers have discovered four key stages with two distinct attitudes in the process of developing an architectural project as a result of their study. The order of the four main phases varies depending on the type of attitude, which is further detailed, and each of these phases is carried out using tools and a certain methodology, which is as follows:

1. A description of the project's objectives, biological research, and resource search in the biological area to address the issue and carry out the project's objectives and policies. Before 2013, a biological specialist assisted and accompanied studies in the biological field. Biological investigations might be carried out more independently by architects and engineers thanks to the development of tools like BioTRIZ, FOBIE, and databases like E2BMO or AskNature. At this point, biological research is used to help choose the biological model.

2. The design idea is presented by selecting the guiding principles of life and taking into account the design guidelines. Biological functions are categorized, isolated, and extracted during this step to be coded, utilized, and mimicked.

3. Information coding is the first step in the simulation of biological data gathered from sources in the biological field. Information simulation is carried out in two steps during this phase. In the experimental stage, a model constructed using natural processes and life's fundamentals is simulated. You can use a visual programming language or a textual programming language to transmit these data to the architectural domain.

4. State-based algorithms are used to transmit biological information to the architectural domain. To accomplish the predetermined objective of the architectural domain, this phase involves using algorithms in the field of architecture and obtaining the physical elements and components of the architecture. The prototype that comes out of this phase can be validated utilizing the analyses that the algorithms give.

The core of the problem-based approach is the "quiddity of the research challenge." A human need or problem is first identified in the problem-based process, and then designers, working with biologists or using biological databases, explore nature to identify a solution that organisms have used to handle a related problem. The analysis and classification of human difficulties, restrictions, and functional needs precede the conduct of biological research because designers employ this method to successfully identify essential objectives and design criteria. In that, the original design policy is created first by human aspects and functional needs, and the biological studies are then conducted by the initial design policy. It explains the general design philosophy. The nature design strategy is identified in the next step by the overall design philosophy, and as a result, the principles of life are chosen. The extraction, separation, and classification of biological data can be used to create the framework and basis of the strategy. The next step involves coding the classified data. By extracting, separating, and classifying biological information, the foundation and basis of the plan can be established. In the following phase, by coding the classified information, they can be simulated, and some suitable prototypes can be generated and presented (Fig 5).

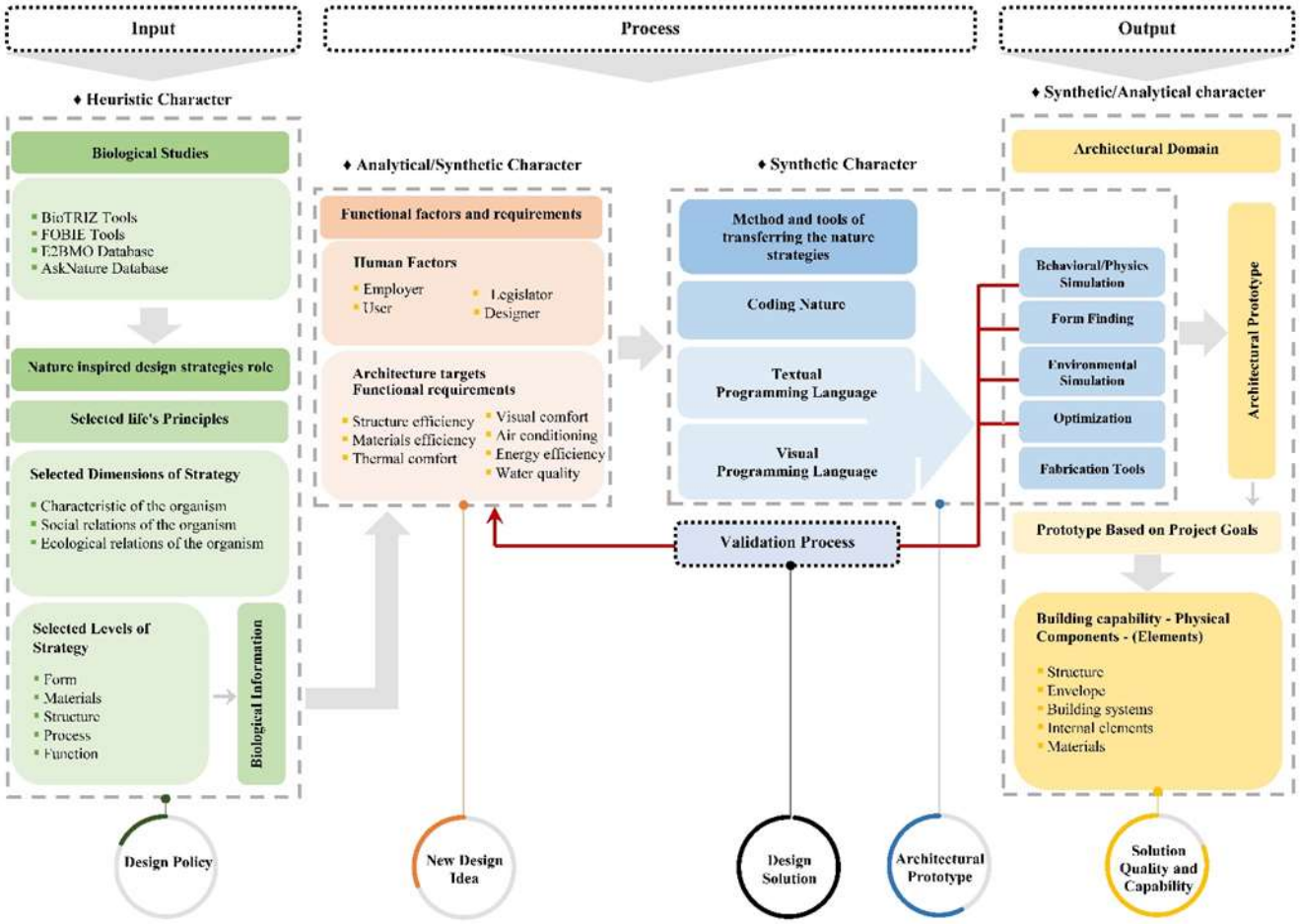


Fig 5 Diagram of the attitude, method, and tools of transferring nature design strategies in the process of creating architecture inspired by nature based on a solution-based approach

Instead of focusing on particular design issues, a solution-based approach bases its design process on biological knowledge and research. "The existing potential determines the quiddity of the research problem" is the fundamental of the solution-based approach. The biological source and the life principles are first discovered and chosen, and then carefully analyzed in many biological dimensions and levels so that they may be used as the foundation and basis of the design and can also be imitated and used. This is how biology influences design. This implies that biological information can be extracted, distinguished, and categorized in this phase before being coded in the following step to replicate it (Fig 6).

The two approaches are similar in that they both involve design strategies that are inspired by nature. The distinction between these two attitudes can be seen in the traits of the first and second stages of the architectural creation process. Phases one and two of the solution-based approach have exploratory and analytical-combination qualities, respectively. However, with the problem-based method, phase one has analytical-composite qualities, while phase two has exploratory characteristics. The two approaches differ in that: with the problem approach, design is founded on biology; this means that the human problem or need is first generated, and then designers work with biologists to solve it. They investigate nature and locate the answer within nature using biological

databases. Designers can efficiently use this method to pinpoint key objectives and design criteria. Since that biological research is carried out following an analysis and classification of human issues, constraints, and functional needs. Instead of focusing on solving specific design issues, a solution-based approach relies on biological knowledge, research, and design, and biology has an impact on design. To accomplish this, the biological source and the principles of life must first be identified and chosen, and then they must be thoroughly examined at various levels and dimensions of biology. These studies are of a type that can be effectively used as the framework and basis for the strategy."

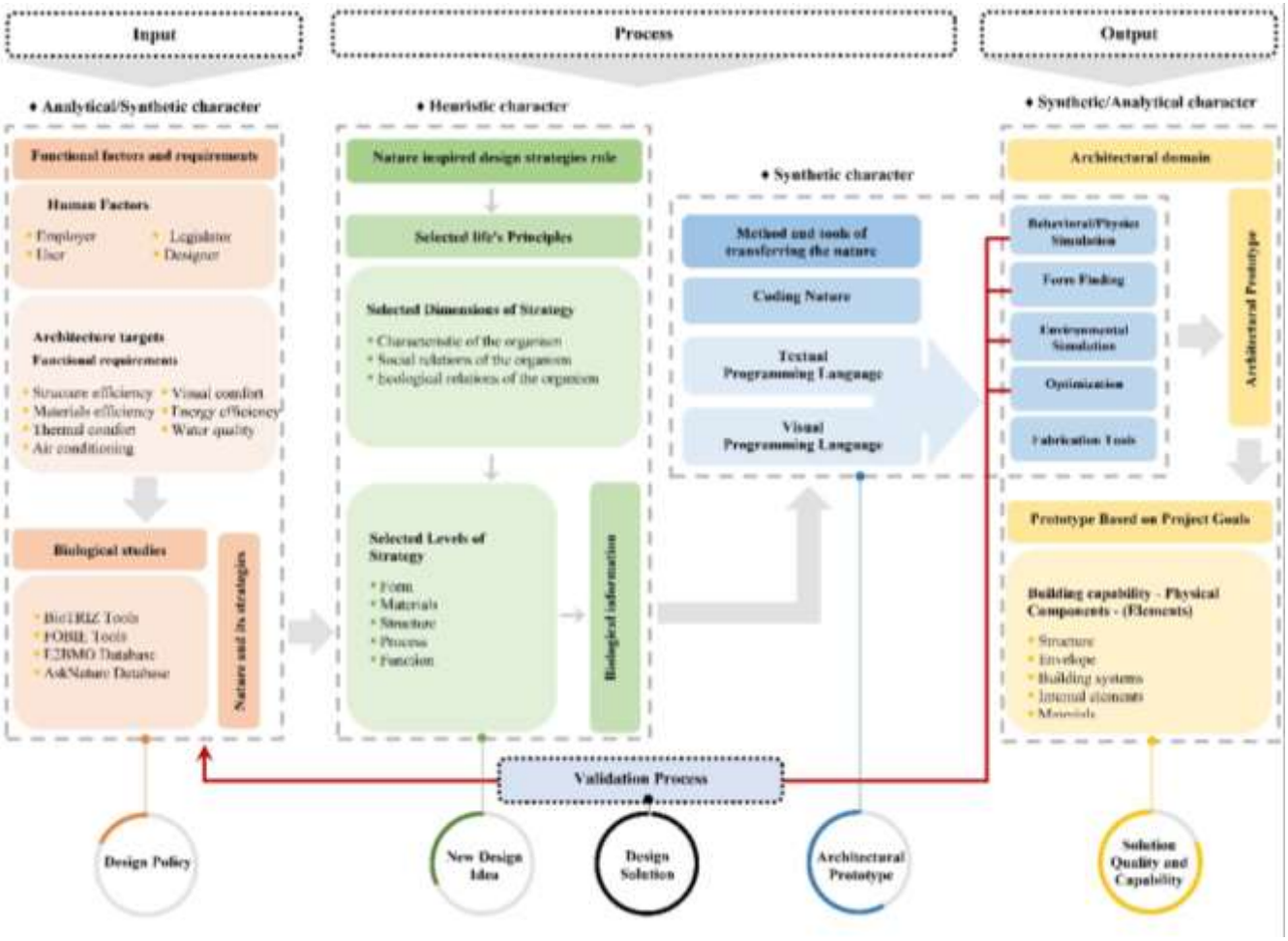


Fig 6 Diagram of the altitude, method, and tools of transferring nature design strategies in the process of creating architecture inspired by nature based on a problem-based approach

References

AIGA, The professional association for design. (2010). Report: The living principles. New York: Center for Sustainable Design.

Bakker, C. A., Wever, R., Teoh, C., & de Clercq, S. (2009). Designing cradle-to-cradle products: a reality check. *International Journal of Sustainable Engineering, 3*, 2-8.

Baumeister, D. (2011). *Introduction to Biomimicry*. U.S. state: Arizona State University.

Benyus, J. (2002). *Biomimicry: Innovation Inspired by Nature*. Harper Perennial.

Brezet, J., & van Hemel, C. (1997). *Ecodesign, a Promising Approach to Sustainable Production and Consumption*. Paris: United Nations Environmental Programme (UNEP).

Brink, G., Destandau, N., & Hamlett, P. (2009). *Genealogy of the Living Principles*. New York: Center for Sustainable Design (AIGA).

Charter, M., & Tischner, U. (2001). *Sustainable solutions: developing products and services for the future*. Sheffield: Greenleaf publishing.

de Pauw, I. (2015). *Nature-Inspired Design*. Delft University of Technology, Delft, the Netherlands.

de Pauw, I., Kandachar, P., Karana, E., Peck, D., & Wever, R. (2010). *Nature Inspired Design: Strategies towards Sustainability*. Faculty of Industrial Design Engineering, Delft University of Technology.

Dewberry, E. L. (1996). *Ecodesign*. Open University.

Ehrenfeld, J. (2008). *Sustainability by design: a subversive strategy for transforming our consumer culture*. Yale University Press.

El-Mahdy, D., & Gaber, H. S. (2017). The behavior of natural organisms as a mimicking tool in architecture. *International Journal of Design & Nature and Eco dynamics, 12*(2), 214-224.

Hallstedt, S. (2008). *A foundation for sustainable product development*. Department of Mechanical Engineering: Blekinge Institute of Technology.

Harman, J. (2013). *The Shark's Paintbrush: Biomimicry and how Nature is Inspiring Innovation*. London: Nicholas Brealey Publishing.

Helms, M., Vattam, S. S., & Goel, A. K. (2009). Biologically Inspired Design: Process and Products. Published in *Design Studies, 30*, 606-622.

Kinppers, J. (2009). Building and Construction as a Potential field for the Application of Modern Biomimetic Principles. *International Biona Symposium*. Stuttgart.

Langrish, J. Z. (2004). Darwinian Design: The Mimetic Evolution of Design Ideas. Massachusetts Institute of Technology. *The MIT Press Journals, 20*(4).

McDonough, W., & Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things*. United States: North Point Press.

Manzini, E. (2009). New design knowledge. *Design Studies, 30*, 4-12.

Margolin, V. (1998). Design for a sustainable world. *Design Issues,14*, 83-92.

Mattheck, C., & Burkhardt, S. (1990). A new method of structural shape optimization based on biological growth. *International Journal of Fatigue,12*, 185-190.

Oxman, N. (2010). *Material-Based Design Computational*. MIT Massachusetts Institute of Technology, Massachusetts.

Papanek, V. (1971). *Design for the real world: human ecology and social change*. New York: Pantheon Books.

Rahimifard, S., & Clegg, A. J. (2008). The role of the engineering community in sustainable development. *International Journal of Sustainable Engineering 1*.

Stevels, Ab. (2001). Teaching modules on eco-design for competitive advantage. *The Journal of Sustainable Product Design, 1*, 273–282.

van Hemel, C., & Cramer, J. M. (2002). Barriers and stimuli for ecodesign in SMEs. *Journal of Cleaner Production, 10*(5), 439-453.

Vincent, J. F., Bogatyreva, O., Pahl, A. K., Bogatyrev, N., & Bowyer, A. (2005). Putting Biology into TRIZ: A Database of Biological Effects. *Creativity and Innovation Management, 14*(1), 66-72.

Weinstock, M. (2008). Versatility and Vicissitude. *Architectural Design, 78*(2), 20-25.

Zari, M. P., & Storey, J. B. (2007). An Ecosystem Based Biomimetic Theory for a Regenerative Built Environment. In *Sustainable Building Conference* (Vol. 7).