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Finding a strategic approach for application of biomimicry in architecture.

Encontrar un enfoque estratégico para la aplicación de la biomimética en la arquitectura.

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ABSTRACT

In the last few decades there has been an increasing interest in bio mimicry worldwide and has led to its emergence as an important theory that looks up to nature as a mentor and model to find out innovative solutions for design. Through the concept of biomimicry, designers realize the organic structures in nature are not only beautiful but also durable, that can be applied to nature-inspired design interventions. As we are heading towards sustainability, biomimicry can be an innovative approach to achieve sustainable design. Here in this paper an attempt has been made to explore the concepts of bio-inspired design and its different methodologies, in order to derive at a systematic approach to design the built environment that mimics the techniques of nature into architecture. Biomimicry has three levels: organism, behavior and ecosystem, in order to generate form, selection of material, construction process, and establishing it to function. From the literature, 5 aspects of each level of biomimicry were identified and compared with 5 areas of architectural interventions. Opinions of industry experts and academicians were recorded through questionnaire survey on a 5-point Likert-type scale which were then analyzed using t- test. The aspects of each level of biomimicry were then ranked according to their favorability of applications with respect to the area of architecture. This ranking system clearly explains the best suited aspect for each level of biomimicry in a concerned area of architecture as per the requirement.

Keywords: Biomimicry, organism, behavior, ecosystem, architecture.

RESUMEN

En las últimas décadas ha habido un creciente interés en la biomimética en todo el mundo y ha llevado a su surgimiento como una teoría importante que mira a la naturaleza como mentora y modelo para encontrar soluciones innovadoras para el diseño. A través del concepto de biomimética, los diseñadores se dan cuenta de que las estructuras orgánicas de la naturaleza no solo son hermosas sino también duraderas, lo que se puede aplicar a intervenciones de diseño inspiradas en la naturaleza. A medida que nos dirigimos hacia la sostenibilidad, la biomimética puede ser un enfoque innovador para lograr un diseño sostenible. Aquí, en este documento, se ha hecho un intento de explorar los conceptos de diseño bioinspirado y sus diferentes metodologías, con el fin de derivar en un enfoque sistemático para diseñar el entorno construido que imite las técnicas de la naturaleza en la

arquitectura. La biomimética tiene tres niveles: organismo, comportamiento y ecosistema, con el fin de generar forma, selección de material, proceso de construcción y puesta en funcionamiento. A partir de la literatura, se identificaron 5 aspectos de cada nivel de biomímesis y se compararon con 5 áreas de intervenciones arquitectónicas. Las opiniones de expertos de la industria y académicos se registraron a través de un cuestionario en una escala tipo Likert de 5 puntos que luego se analizaron mediante la prueba t. Los aspectos de cada nivel de biomímesis se clasificaron luego de acuerdo con su favorabilidad de aplicaciones con respecto al área de la arquitectura. Este sistema de clasificación explica claramente el aspecto más adecuado para cada nivel de biomímesis en un área de arquitectura en cuestión según el requisito.

Palabras clave: Biomimética, organismo, comportamiento, ecosistema, arquitectura.

INTRODUCTION

Architects while designing use their understanding of the principles and theories of architecture to design their buildings. The theories of architecture are many and they form the theoretical base for the design work of architects. Some of these are normative (norms based), thematic (theme based), analogical, proportion systems, chronological. Out of these theories the analogical theory is used extensively. Analogical theory can be placed under several heads some of which are mathematical, romantic, mechanical, biological and some others.

Of the analogical theories, the biological analogy has been used over the ages by architects worldwide. Architects from the times of Vitruvius, Leonardo Da Vinci, and in recent times Santiago Calatrava have used bio mimicry most passionately in many of their design works.

“Look deep into nature and you will understand everything better” Albert Einstein.

Nature is the mother of all creations on earth. Bio mimicry is a theory derived from nature and its magnificent creations. History speaks how nature has been a great source of information and inspiration for human being on all aspects of life. Having looked into architectural theory in general this research intends to investigate biological analogy and particularly the issues pertaining to the theory of biomimicry.

Table1. Comparison of nature as model, measure & mentor.

NATURE AS MODEL	NATURE AS MEASURE	NATURE AS MENTOR
Biomimicry is a new discipline that studies natures model, gets inspired from designs and then imitate the processes to solve human problems.	Biomimicry uses a standard to deduce the “rightness” of our innovations. It defines what works, what is appropriate and What lasts.	Biomimicry is a new approach of viewing and understanding nature. This is an era based on what we can extract and utilize from the natural environment.

*Source: *(Elmokadem2, n.d.)*

This research papers shall focus on the clear understanding of biomimicry – an inspiration from nature. How to delineate – "DEFINATION OF BIOMIMICRY "WHAT IS IT AND WHAT IS NOT !!!" Basically, the purpose is to bridge the gap by understanding process and recommending guidelines for selection of levels of biomimicry for specific purposes.

EXISTING KNOWLEDGE

The definition of biomimicry is explained and defined in various aspects by different researchers. For example:

- Benyus (1998), defined Biomimicry: "a new discipline that studies natures best ideas and then imitates the designs and process to solve human problems".
- Guber (2008) defined Biomimicry as "the study of overlapping discipline of biology and architects that show innovative potential for architectural problems".

There are two approaches in biomimicry:

- Biology to design approach
- Design to biology approach.

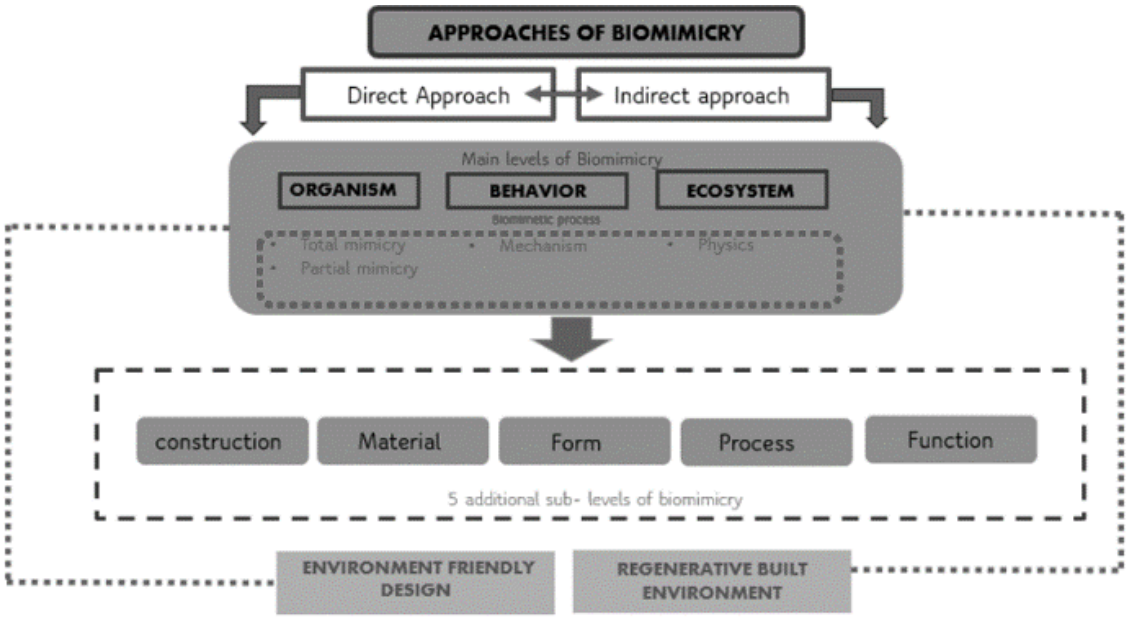

Fig 1: Approaches of biomimicry.

*Source: Self

Here, learning about the three levels of biomimicry and its aspects have been analyzed and tabulated below. The three levels of Biomimicry are:

I. Form/Organism – Imitating geometry or shape,

II. Process/Behaviour – imitating the process,

III. Ecosystem – Imitating the geometry, process and material.

Under these three levels various aspects were identified from the literature.

Table 2: Levels of Biomimicry - Aspect of Levels.

	LEVELS OF BIOMIMICRY		
ASPECTS OF LEVELS	ORGANISM	BEHAVIOR	ECOSYSTEM
	Formal attribute: ex size and shape of termite.	Risk management: Ex PITCHER PLANT	Adjustment as per change in surrounding Ex: CHAMELEON
	Function & behavior: ex Termites swarm in order to mate and start new colonies.	Collaboration and teamwork: ex pitcher plant with bat.	Adaptation with ecosystems Ex: Cactus • Thick, waxy skin to reduce loss of water and to reflect heat. • Fleshy and big stems to store water. • Spikes of cacti are meant to protect them from animals wishing to use stored water. • Deep roots in order to tap groundwater.
	Morphology, anatomy & pattern: Ex internal anatomy of termite.	Survival techniques: ex THE VENUS PLANT	Management with less resources Ex: Cactus in desert • lack of food, water or light.
	Organisms & hierarchy of parts & systems. Ex termite life cycle.	Sensing, responding and interaction Ex: TOUCH ME NOT PLANT	Waste management Ex: Nitrogen fixing bacteria.
	Self-assembly Ex: Swarm Intelligence – ANTS.	Hierarchy of community members Ex: There are seven main taxonomic ranks: kingdom, phylum or division, class, order, family, genus, species	Climatic response Ex: TERMITE MOUND cooling, heating and ventilation solution to fix climatic factors.

**Source: Self*

Table 3: Architecture has been categorized into following broad areas:

ENGINEERING	Engineering in architecture combines all aspects of building design and construction, including mechanical, electrical, structural drawings, calculations, and other notions of mathematics.
AESTHETIC	The aesthetics of a building is a vital aspect considered in architecture. The appeal of a building covers the combined effects of a building's shape, size, texture, color, balance, unity, movement, emphasis, contrast, symmetry, proportion, space, alignment, pattern, decoration, culture and context.
SOCIAL	Social impact on architecture is the conscious design of an environment that encourages a desired range of social behaviors leading to formulate desired set of goals.
SPACE & AREA	Space in architecture the focus is primarily on the enclosed area. However, the relationship between a building and its surrounding is nonetheless a critical part of design. Architecture occurs at the point where form and space come together
CIRCULATION	The term 'circulation' refers to the motion of people through, around and between buildings and other parts of the built environment. Circulation spaces are areas that are predominately used for circulation, such as entrances, foyers and lobbies, corridors, stairs, landings etc. within any building.

**Source: Self*

THE STUDY

To check the applicability of biomimicry (across 5 aspects of each of its three levels) on the five areas of architecture a questionnaire survey was conducted. The questionnaire was provided to the following professionals:

- Architects – academician and practicing architects and
- Engineers – civil engineers and academician.

The respondents' perceptions were measured using a 5-point Likert-type scale for:

- favorability of aspects of organism level verses area of architecture;
- favorability of aspects of behavior level verses area of architecture;
- favorability of aspects of ecosystem level verses area of architecture;

Table 4: The Likert – type scale used in survey Questionnaire

Rating	Meaning of favorability of aspects (In terms of application in areas of architecture and planning)
1	Very Unfavorable for application
2	Unfavorable for application
3	Neutral for application
4	Favorable for application
5	Most Favorable for application

The IBM SPSS Statistics 20.0 software was employed to determine the level of significance of favorability of each of the aspects across the levels of biomimicry against the areas of architecture. All posited aspects of biomimicry levels against areas of architecture were ranked according to their mean score ratings which were calculated using Eqn. 1 (Ekanayake, & Ofori, 2004).

$$\bar{x} = \frac{1(n_1)+2(n_2)+3(n_3)+4(n_4)+5(n_5)}{n_1+n_2+n_3+n_4+n_5}$$

Where n_1, n_2, n_3, n_4, n_5 represents the total no of responses for favorability based on aspects of architecture as 1 to 5 respectively. The obtained data was subjected to single sample t-test to determine the level of significance of each of the aspects across the levels of biomimicry against the areas of architecture. Critical t-value was calculated with degree of freedom equal to 1 less than the sample size.

RESULT AND DISCUSSIONS

'T'-Test Results for aspects of organism levels with respect to the areas of architecture.

The single sample t-test analysis was conducted to determine the level of significance of favorability of each of the aspects of organism level with each area of architecture. The mean of the favorability was calculated, compared and ranked according to their obtained t-value (to). Table 3, gives an overall summary of the favorability of each of the aspects of organism level in area of architecture.

From the Table the following can be clearly inferred: In the engineering (area of architecture) Morphology, anatomy & pattern (aspect of organism level) is most favorable application in architecture. However, formal attribute is most favorable in case of Aesthetics. Organisms & hierarchy of parts & systems stands out as most favorable aspect with respect to social. In case of space and area, self-assembly is the most favorable aspect. Function & behavior is the most favorable application with respect to circulation of architecture.

Table 5: Cumulative T-test Results of all aspects of organism level verses Area of architecture.

		Areas of Architecture				
Sl. No.		1	2	3	4	5
	Aspects of Organism Level	Engineering	Aesthetics	Social	Space & Area	Circulation
1	Formal Attribute	3.77[2]	26.81[1]	3.16[2]	2.63[3]	2.67[3]
2	Function & behavior	3.52[3]	0.00	0.23	2.58	12.45[1]
3	Morphology, anatomy & pattern	9.71[1]	2.97[3]	2.37[3]	3.44[2]	3.77[2]
4	Organisms & hierarchy of parts & systems	0.12	2.45	16.98[1]	0.79	2.28
5	Self-assembly	0.26	3.19[2]	0.14	9.49[1]	0.43

Table 6: Cumulative T-test Results of all aspects of Behavior level verses Area of architecture

		Areas of Architecture				
Sl. No.		1	2	3	4	5
	Aspects of Behavior Level	Engineering	Aesthetics	Social	Space & Area	Circulation
1	Risk management	3.77[2]	0.09[2]	2.90[2]	0.12	11.83[1]
2	Collaboration and teamwork	3.52[3]	0.00[3]	2.59[3]	16.36[1]	2.32[3]
3	Survival techniques	2.83	-0.41	12.46[1]	3.44[2]	3.52[2]
4	Sensing, responding and interaction	11.54[1]	0.00[3]	2.12	2.46[3]	2.28
5	Hierarchy of community members	0.26	38.72[1]	0.91	2.37	2.08

From the Table the following can be clearly inferred:

Table 7: Cumulative T-test Results of all aspects of Ecosystem level verses Area of architecture

		Areas of Architecture				
Sl. No.		1	2	3	4	5
	Aspects of Ecosystem Level	Engineering	Aesthetics	Social	Space & Area	Circulation
1	Adjustment as per change in surrounding	27.48[1]	2.396	0.69	3.31[3]	0.53[3]
2	Adaptation with ecosystems	3.52[2]	23.90[1]	4.65[2]	0.93	-0.26
3	Management with less resources	0.22	2.405[3]	0.56	3.44[2]	20.75[1]
4	Waste management	2.14	1.89	16.98[1]	0.79	3.02[2]
5	Climatic response	2.85[3]	4.65[2]	0.91[3]	26.81[1]	0.43

In the engineering (area of architecture) Sensing, responding and interaction (aspect of behavior level) is most favorable for application. Whereas, Hierarchy of community members stands out as most favorable application in Aesthetics. Survival techniques is the most favorable application in case of social. In space and area, Collaboration and teamwork stands out as most favorable applications. Risk management is the most favorable aspect in the area of circulation.

From the Table 7 the following can be clearly inferred: In the engineering (area of architecture) Adjustment as per change in surrounding (aspect of ecosystem level) is most favorable for application. However, Adaptation with ecosystems is most favorable in case of Aesthetics. Waste management stands out as most favorable aspect with respect to social. In case of space and area, Climatic response is the most favorable aspect. Management with less resources is the most favorable application with respect to circulation of architecture.

As conclusion, the scale of favorability of the aspects of levels of biomimicry against the areas of architecture and planning were analyzed through statistical analysis along with the development of ranking system. This ranking system clearly explains the best suited aspect for each level of biomimicry in concerned area of both architecture and planning as per the requirement. Further, this research shall proceed with another survey with the experts of biomimicry where we can research and analyze with existing recommendations to come up with specific recommendations based on climate response of particular region in the area of architecture.

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