

Bio-informed Research in the Discipline of Architecture: A Bibliometric Analysis

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Abstract

Bio-informed research reveals innovative, creative and original ideas for the solution to various problems in architectural design and many design disciplines. In the designs that adopt this approach, "nature" can be considered as a "data warehouse" providing various data that can be transferred from nanoscale to mesoscale regarding process, function, material, structure. Within the scope of this study, bibliometric research was carried out in the CumInCAD database to reveal what kind of information and outputs have been achieved through the data/capta taken from nature. In this process, the aim is to discover and understand the conceptual relationships, not only the purpose of the data taken from nature but also the relationships between the data and the patterns. All the data obtained were analysed within the scope of the determined parameters and visuals, including data relations, were prepared. As a result of the study, it can be seen that the bio-informed studies examined in this paper have the potential to open up a wide range of new research in the discipline of architecture. The findings show that the biomimetic approach has set the stage for the scientific and interdisciplinary studies that have the potential to change paradigms in architecture.

Keywords

biomimetic(s), bio-informed, biodesign, data visualization, CumInCAD, data, architectural design

1 Introduction

For more than 3000 years, people have learned from nature to produce solutions to their problems and to inspire their designs (Vincent et al., 2006). Biomimetic science as a learning approach from nature, in the guide published by the German Biomimetic DIN Standardization Institute (International Organization for Standardization, 2015), defines biology and technology disciplines as uniting them to solve technical problems through the abstraction, transfer and application of the information obtained from biological models. Biomimetic science covers a wide range of research topics, affects various fields of application and is thought to have a significant scientific, social and economic impact on the quality of life (Lepora et al., 2012). While the research conducted on this issue is becoming increasingly popular, the terms, terminologies and concepts emerging in this field also create a more comprehensive, interdisciplinary and complex field of research. In this case, it becomes difficult for researchers to understand these terms, terminologies and concepts, conduct research in a common language and comment on the results.

In this study, a conceptual analysis was carried out to understand and comment on nature-driven and bio-informed studies included in the architectural literature as a result of interdisciplinary studies. The main target in the investigation of these studies that have entered the literature is to discuss the meanings/reasons behind imitating nature. In line with this goal, a series of keywords that can perform conceptual analysis has been determined, and with these keywords, nature-driven/bio-informed studies in the CumInCAD¹ database have been scanned (Computer Aided Architectural Design; eCAADe). Studies obtained at the end of the process - keywords scanned (bio-inspiration, biomimetic, biomimicry, bionic(s) biology, bio, learning from nature). The data obtained by analyzing the determined titles such as the biotic or abiotic status of the reference taken from nature, the characteristics

¹ The CumInCAD database, opened in 1998, is a bibliographic index compiling articles on computer aided architectural design (Computer Aided Architectural Design; eCAADe).

investigated in nature, the context of the researches in which these features are used in architecture and which subjects they cover, the performance criteria targeted by these studies and the final product in the architecture are presented by visualizing. "Information analysis techniques" were used to apply objectively the method used in this study. An important aspect of this type of analysis of large datasets is how the results are visualised. Friedman (2008) states that the main purpose of data visualisation is to convey information clearly and effectively with graphical methods. From this point of view, various visualisation techniques, including graphics and related diagrams, have been used to develop and present a series of perspectives on the results of the analysis.

2 Conceptual analysis in literature

In the disciplines where nature-driven studies are carried out, an adaptation process takes place to find quantitative and qualitative ideas, such as transferring information between scales, applications, processes or involvement, and a design solution is achieved. The solution to the problems encountered due to differences in nature, such as scale, material, form, process, system, and vitality is limited to the biological knowledge of the designer. In this context, it is possible to claim that the problem of transferring information between fields can be eliminated in nature-oriented research supported by a multidisciplinary working environment.

The principal aim in nature-based studies is the adaptation of methods and systems in nature to synthetic structures. In this context, natural systems that operate smoothly within their cycle and ecosystem provide an essential database for "synthetic paradigms". In the field survey conducted for this purpose, it was observed that the first studies carried out started systematically with technical designs such as vehicle, ship and aircraft designs in the 1950s. This process is called model-based biomimetic. By the 1980s, rapid developments in measurement, observation, design and production technologies provided a more comprehensive understanding of nature and provided access to information at levels ranging in different scales for those conducting biomimetic research. Along with the technological developments that have gained momentum since the 1990s, fields such as computer science, nanotechnology, mechatronics and biotechnology have brought biomimetic studies to the upper levels. Today, biomimetics is accepted as a scientific discipline that requires an interdisciplinary approach and leads to the production of new products and technologies.

Nature has developed forms, structures, materials and processes that function from macro scale to nanoscale. In this context, it is interpreted as a large data source and operating system such as a warehouse, inventory or catalogue with potential "design solutions" for the designer. To expand such a "perception of nature" and biomimicry, many websites such as asknature.org have been established (Dicks, 2016). Studies have been carried out to increase interest in the possible activities in this field in a popular language.

In this study, biomimetic science-related concepts were scanned in the CuminCAD database, where studies in computer-aided design are presented, and conference publications indexed; the aim being to reveal the data and data relations within nature-based studies. The most important reason for determining this database for research is that it includes computer-aided art-design-technology research and related conferences, including current studies on subjects such as biomimetic, biotechnology, synthetic biology, and technological nature perception.

In this context, a set of data visualisation was carried out to understand better, present and interpret the data and data structure obtained. It is thought that it is possible to establish a relationship between the data and to obtain meaningful results by visualising the data.

The data visualisation approach is prominent in increasing the understanding of the concepts and discovering new relationships. Data visualisation is defined as "interactive visual presentations prepared to facilitate understanding and conceiving of a subject". It is made for researchers to understand complex data and to make informed decisions (Neşeli and Topaloğlu, 2016). For this reason, data visualisation, which is seen as an effective approach and is valuable in terms of structuring data, regularising and organising interrelated data, making information visible and interpretable, and visualising the conceptual structure adopted as a method in this study. Bibliometric Analysis was performed to visualise the data. Bibliometric Analysis is a quantitative method used to analyse the information structure and development of the research areas based on the analysis of the related publications. It includes a review of the literature showing the number, evaluation and main trends of publications on a particular subject (IGI Global PUBLISHER of TIMELY KNOWLEDGE). Bibliometric studies are based on analysing certain features of the document's content or publications and obtaining various findings related to scientific communication (Al and Coştur, 2007). In this context, the bibliometric analyses carried out in this study can be seen in Subsection 2.1.

2.1 Data visualization

The study was conducted through articles taken from the database by filtering with the keywords "biomimetic(s), learning from nature, biomimicry, bionic(s), bio-inspired (bio-inspired), biomimesis, bio-based, bio-driven, biotechnology, bio-, biology" and aims to analyse information in the CuminCAD database without any historical limitations. The scanning was carried out to cover the studies between 2004–2019. Revealing the potential characteristics of the data through searching and filtering, and by creating a set of data covered by these approaches, the structure and the relationship between these data have been clarified. By organising data from the CuminCAD database, the aim is to reveal and explore the information discovery process and the relationship between the patterns, concept relations, the purpose of the data from nature, the data and the patterns. The 139 articles obtained as a result of the screening were first analysed by year (Fig. 1). Since the exercise was carried out before 2004, it is thought that the database in question indexed the studies after this year.

Looking at Fig. 1, it can be seen that the studies carried out in this field are greater in 2008, 2012 and 2017 compared to other years. In the scans from this graphic, it is understood that most studies are related to the concept of biomimetics, followed by the concept of biomimicry.

This process, which is designed based on articles obtained in the light of concepts, is planned as determining the data, processing the data, describing the data patterns and reaching the information in the light of the formed patterns. Thus, with this process, the aim was to reveal and interpret relevant, useful information that was hidden in the data. It is thought that the findings obtained as a result of these procedures are important in terms of understanding the scale and type of natural phenomena, learning dimensions and reflect on the architectural product. In this context, firstly a graphical analysis of the most frequently used keywords have been carried out through 139 articles tagged as "biomimetic(s), learning from nature, biomimicry, bionic(s), bioinspired (bio-inspired), biomimesis, bio-based, bio-driven, biotechnology, bio-, biology" and the results are given in Fig. 2. The graphic is a visual representation of the frequency of terms in a more extensive set. It is obtained by scaling depending on the frequency of the concept.

When Fig. 2 is examined, it is seen that concepts such as design, computational design, parametric design, digital production are frequently used together. One of the critical

factors of this result is that the complexity of biological data can only be learned through computational tools and environments and then interpreted and transferred to design.

The articles were then subjected to a new analysis under the titles such as the biological phenomena examined and the purpose for examining these phenomena, how they are transferred to the architectural product and the type of problem for which a solution was sought. As a result of such an analysis, the focal points and relational data flow chart in nature-oriented studies trying to develop different dialogues with nature were created. This "flow chart" was prepared using the Sankey Diagram² (SankeyMATIC), which shows extensive data relationships to provide visual analysis and a holistic view of complex relationships (Data Visualization Catalog).

The data type analysed (data or capta)³ are data that is processed electronically (summarised, sorted, classified, analysed or simply blended and associated with other appropriate data), reformatted and presented to obtain meaningful and useful information.

As seen from the created Sankey diagram (Fig. 3), concepts such as biomimetic(s), biomimicry, bionic(s), learning from nature, bio-inspiration appear in the same article and it is concluded that they are accepted as synonyms. In all these studies aiming to learn from nature, it was observed that most biotic factors were investigated, and in widely different scales such as DNA, cell and ecosystem.

Observed process-oriented studies are the results of research at different scales such as morphogenesis, metamorphosis, evolution, self-creation, life cycle, and ecosystem. Here also, the existence of the concept of abiogenesis is questioned. It is seen that the evolutionary process

² The Sankey Diagram in this study was prepared with (SankeyMATIC).

³ Checkland and Holwell (1998) define the first data that objective facts are not obtained as data, but if this data is obtained as part of an information system or as a result of interpersonal communication it is called capta. Data is expressed as a large number of objective facts that exist in the universe that can be measured and/or collected. On the other hand, Capta is data defined as worth collecting and associated with a context and presented with a visualization. The process of choosing a capta from the data is mental and subconscious. The data selected for a specific purpose or subject becomes a captaInformation, and also a means for choosing and summarizing data and presenting it as useful for the recipient (UPSpace Institutional Repository). However, phenomenology researchers define "capta" as the data seen, thought and felt and "data of conscious experience" (Wilden and Hammer, 1987:p.315). That taken in the analysis can be summarized as: capta, those given before the analysis: data (Lanigan, 1994).

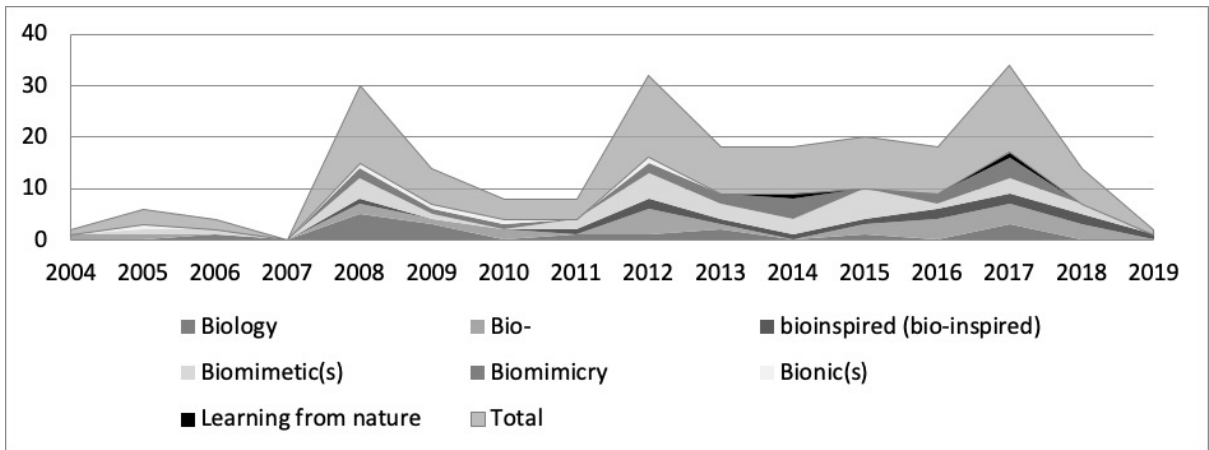


Fig. 1 The number of articles resulting from scans with keywords

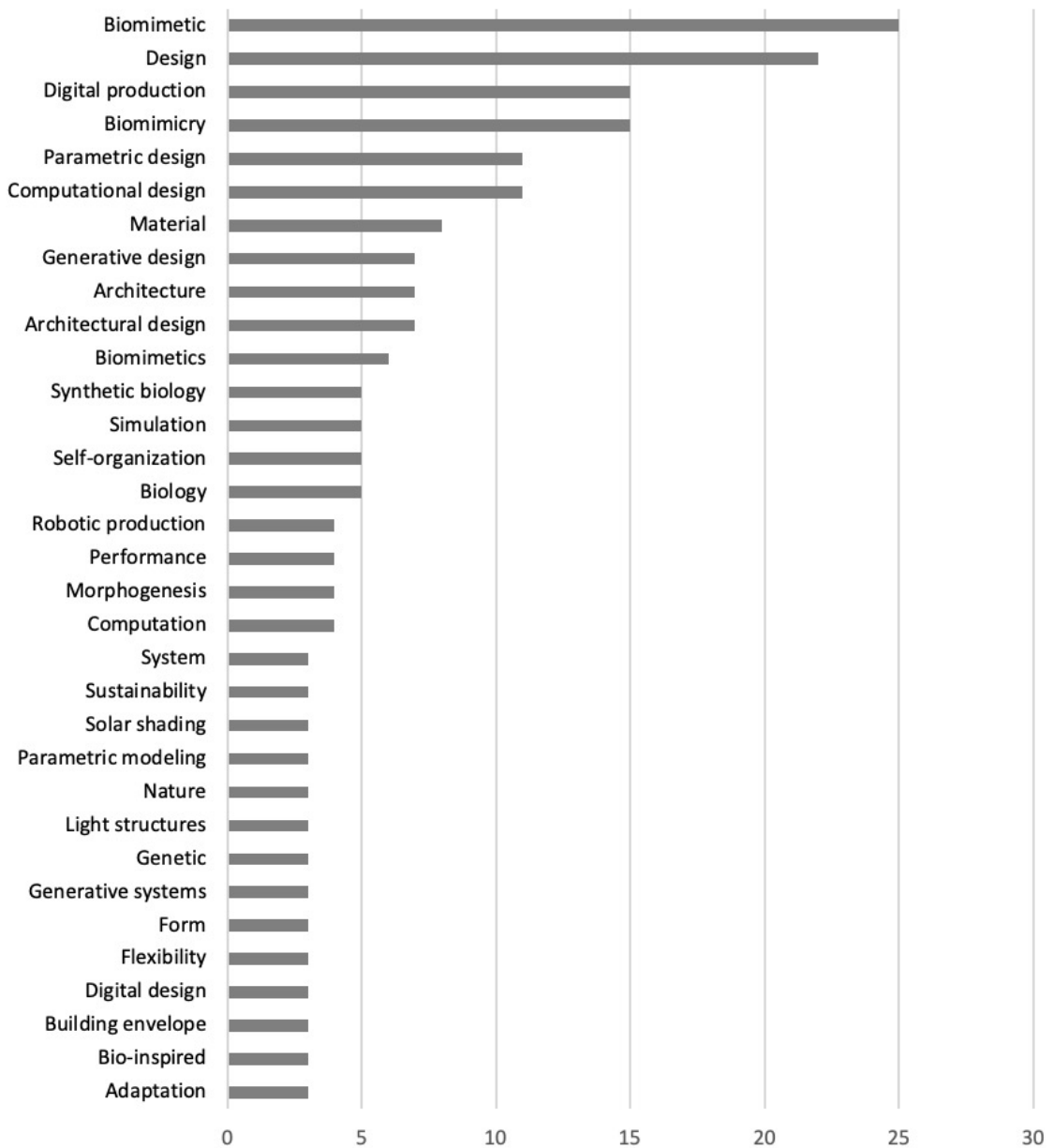


Fig. 2 Graphic prepared based on keyword frequency

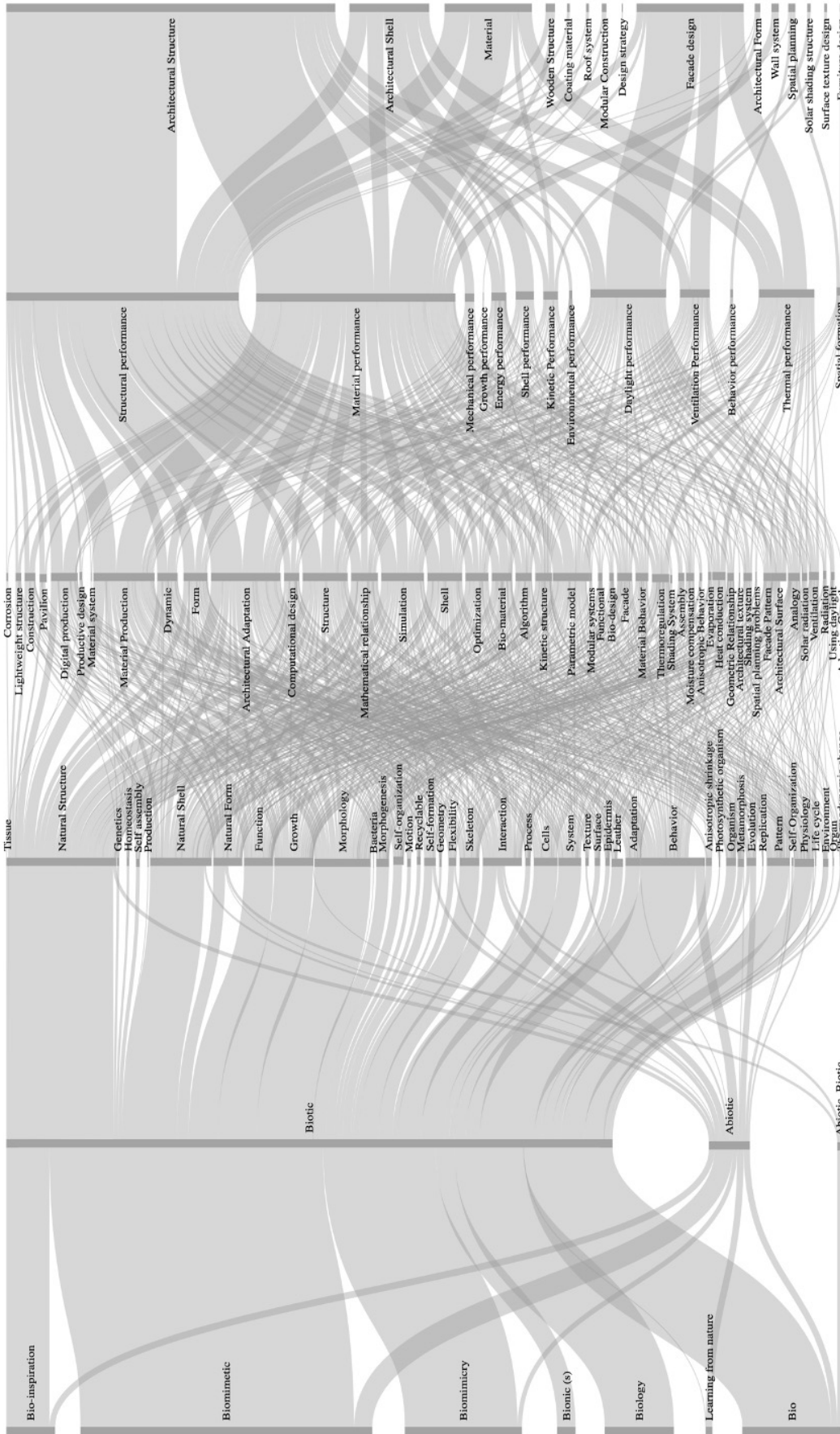


Fig. 3 Sankey diagram

in nature is applied to architectural solution processes through models, simulations and production techniques developed in the digital environment. In this process, technical models are created by studying biological principles/structures as a result of detailed analysis. There is also philosophical discourse behind the research into the way a living creature completes itself and continues its existence in architectural products.

The multidisciplinary nature of research is one of the strengths of biomimetic studies. In this field, scientists and researchers come together in fields such as biology, chemistry, physics, engineering and architecture. Thanks to these interactions and relationships, it is seen that studies increasingly demand that natural materials, which create beneficial resource potential, be recycled or biodegradable, with the answers to ecological concerns being sought both quantitatively and qualitatively. Another key issue that arises in the analysis is that the related disciplines in biomimetic research in architecture are mostly biology, mathematics, computational science and physics.

In the diagram created with these, it is seen that the performance-based aspects of nature and the living creatures it contains are taken into consideration in architectural design. These principles of performance learned from nature in architectural design are carried out together with form, process, function and behavioural studies. From this point of view, learning outcomes in which the information transfer from nature to architecture is carried out in the context of biological paradigms can be expressed in the following concepts as shown in Fig. 4; the performance criteria that are targeted at the primary learning outcomes are listed in Fig. 5.

The concept of "performance", which is the harbinger of a paradigmatic change in architecture, is to restructure the form; it is a driving concept for design that helps transform natural, cultural and social environments into a synergetic

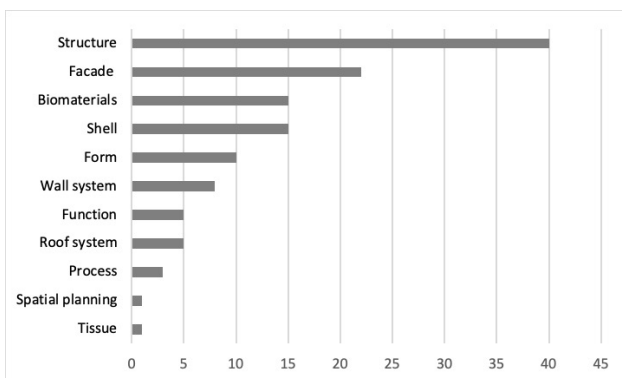


Fig. 4 Architectural concepts frequently derived from nature

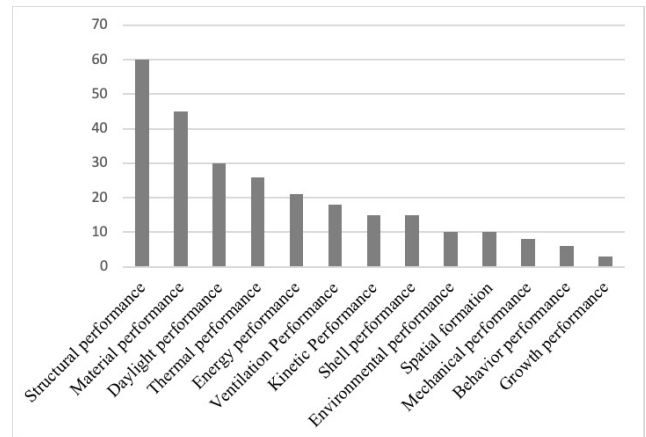


Fig. 5 Architectural performance criteria of learning outcomes

relationship with its dynamics, thereby determining performance capacity. The concept of "performance" as the target of the studies is related to the discipline of architecture and is directly related to the biological paradigm. The intended performance criteria enable the form, structure, and shell's performance capacity to be determined and restructured, thus enabling it to act together with the dynamics of nature.

3 Conclusion

In these examined studies, it is seen that architectural research deals with nature in the context of a technological perception and that architecture, biology and technology are intertwined. Despite the brief relationship between these disciplines, it is difficult to find a suitable bridge to transfer information between the disciplines of architecture and biology, and this problem remains a current research topic. It is essential that researchers who work on this issue hold onto an existing method or suggest/determine a new method to obtain meaningful information as many different areas can adapt to the principles of nature and an unlimited number of samples suitable for study.

Along with architecture, biological production and synthetic biology applications, architecture brings different perspectives to biomimetic applications. The underlying reason behind the impact of biological knowledge on the world of architecture can be interpreted as an attempt to redefine the architectural/built environment as a broad part of the ecology. In addition, data processing potential continues to increase rapidly. In this context, we can interpret our world with a history of 3.8 billion years as a data catalogue with research and development features.

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