LEARNING FROM NATURE: EXPLORING SYSTEMS OF PLANTS AND ANIMALS FOR FORM GENERATION

Arnis Rochma Harani

Department of Architecture
Faculty of Engineering
Universitas Diponegoro
Indonesia

Published: 2023-04-30
Submitted: 2023-03-25
Accepted: 2023-04-24

ARSNET, 2023, Vol. 3, No. 1, 32–45
DOI: 10.7454/arsnet.v3i1.73
ISSN 2777-0710 (online)
ISSN 2777-0702 (print)

Abstract

This paper aims to explain learning strategies for deconstructing and reconstructing natural objects as hidden knowledge in nature for application in design studio pedagogy, particularly in developing architectural forms. Current discourse on nature-based architecture learning often places nature as a form of metaphor and analogy. This article presents various results of tracing natural systems, especially plants and animals, as a basis for learning architecture in the Basic Design studio at the Department of Architecture, Faculty of Engineering, Universitas Diponegoro. The implementation of the design studio was conducted by groups of students who explore different types of plant and animal objects. The students were assigned to explore all the interesting aspects of the selected object's system in order to gain specific knowledge beyond the physical. The studio outputs demonstrate an exploration of new architectural forms based on the hidden knowledge of nature. The exploration method of this study follows the pedagogical process in the studio with data collection being carried out periodically through direct observation during model-making time. The learning result of this studio triggers students to be aware of the various hidden knowledge in the environment that can be used as a basic system for developing architectural forms.

Keywords: nature, nature system, hidden knowledge, design studio, architectural form

Correspondence Address: Arnis Rochma Harani, Department of Architecture, Faculty of Engineering, Universitas Diponegoro, Jl. Prof Soedarto S.H., Tembalang, Semarang, Central Java, Indonesia.
Email: arnisrochmaharani@lecturer.undip.ac.id

Introduction

This paper discusses the process of learning sensitivity in reading natural systems as the basic principles of architectural presence in the context of a first-year design studio. The first year in the design studio requires a pedagogical method that can improve critical and creative thinking and communicative techniques; triggering the students to be more innovative in the design process (Lee, 2012). One of the possible benefits of learning from nature is its importance as the basis for the development of forms. This study argues that the utilisation of plants and animals in architectural studios can be expanded beyond simply as the basis of an architectural metaphor. This project does not obscure the physical plants and animals as objects to be studied but instead, emphasises the systems that constructed objects. This expands Ball's (2009b) argument that nature's various attributes store life systems beyond their physical appearance. Object nature is not only an order but also a guiding principle (Vidler, 1977). It is important to deconstruct natural objects to study their rules and to find their essence (Ball, 2009a; Vidler, 2013). This paper focuses on the description of learning strategies to train students' sensitivity to the basic knowledge of a context through learning from nature as the potential to enrich architectural forms. With such sensitivity, students are able to study forms, functions, systems, and mechanisms in presenting architectural forms, not only imitating nature but using the rules contained as hidden knowledge.

This article expands the discussion of forms and functions based on systems of nature in the context of architectural design studios. The purpose is to allow students to practice deconstructing objects and reading rules to find the essence beyond their physical form. The explorations show what Ball (2009a) revealed that nature has a pattern which can appear very different from its physical form. Patterns in nature possess various rules that can be read as knowledge (Ball, 2009b). Theoretical discourse related to the architectural pedagogical perspective on learning from nature will be described in this paper, particularly on how to reveal hidden knowledge from nature to develop architectural form. This paper describes the process of deconstructing the object's nature to obtain rules and reading the systems and mechanisms within which then become a basis for reconstructing architectural forms. Various forms of student explorations in dismantling natural objects are discussed as an extension of learning from nature in architectural pedagogy discourse. In addition, this paper discusses how the Basic Design studio exists as a bridge for new students to get to know architecture, not only as a building product or object but also through various things that are easy to find in the surrounding of nature.

Learning from nature in architecture discourses

Theoretical discourse related to learning from nature in the field of architecture has been widely discussed but not much related to the pedagogical perspective of architecture. This

paper discusses the method of learning form, function, and system from nature in the Basic Design studio. Nature stores various secrets that can enrich knowledge from various fields (Ball, 2009a), one of which is architecture (Pioz, 2014). Nature is a source of inspiration (Forty, 2000) in the field of architecture. Various architectural objects are composed of mimesis or metaphors from nature. Studying the efficiency of nature can be done by observing its geometric patterns and by studying the coherence between forms and structures (Pioz, 2014). The paradigm of learning from nature as 'a source of inspiration' is now starting to shift to 'nature as a system.'

Learning from nature can lead to innovative and performative design results (Moosavi, 2022). It depends on how we study nature, not only from the physical form but also beyond the physical. This paper argues that learning from nature—apart from its physical appearance—can reveal hidden knowledge of systems and mechanisms that cannot be seen on a visual basis alone. This expands what Pioz (2014) revealed that learning from nature is not limited to the mimesis of natural forms or the inspiration of organisms. Furthermore, Pioz (2014) said,

> ....the morphogenesis of the natural structures and their bio-technological behavior in order to learn from the logic and the laws of flexibility, adaptability and energy conservation of living species. Thus, through the analysis of the resistant behavior of bird bones, shells of mollusks, linear structures of spider webs, or arborescent networks of lilies, ferns or trees, just to name a few, we have obtained conclusions that open doors to new models and technical structures and construction. Learning to look at nature with eyes to the scientific and artistic pair that can be an endless source of creative suggestions for architects and engineers. (p. 3143)

Suryantini et al., (2022) said that nature is an aspect that constructs the architectural space and therefore learning from nature is important to understand architectural space. On the other hand, Ball (2009b) said that nature holds various hidden aspects that can only be revealed through a detailed investigation and different perspectives are required in studying nature to produce different results. Learning from nature encourages the examination of more interrelated disciplines in architectural design (Abusafieh, 2022), not only nature as a form that can be mimetic but also from its anatomy, systems, and mechanisms as the main focus of this studio. This shows that learning from nature potentially demonstrates richness that can reveal various knowledge in architecture.

This paper argues that learning from nature is not limited to inspiring the form-making process. Instead, the function and mechanism of natural systems can also be used as the basis for the development of architectural forms. The implementation of architectural design studios generally begins with a form of research as a way to enable students to acquire knowledge and apply it throughout the design process (Park et al., 2023;

Saghafi, 2021). Learning from nature enables a shift from objects to processes as the basis of creative thinking and creation. Apart from introducing a variety of knowledge in nature, the studio process that employs such knowledge as the basis for the formation of form architecture is one of the important methods that enable students to have creative thinking. This is one of the architectural studio methods that train students to be more innovative and affect students' motivation positively (El-Mowafy & Hassan, 2023a).

Method

The study discussed in this article is the result of a Basic Design studio project at the Department of Architecture, Universitas Diponegoro, Indonesia. The studio project was conducted by first-semester students. Qualitative observations and analysis were carried out toward the studio works that lasted about four months from September to December 2022. The project aims to develop students' sensitivity to systems of nature beyond the visual form, prioritising students' abilities to explore various hidden knowledge from nature. This project was divided into three main objectives which are: (1) deconstruction of the plant system; (2) deconstruction of the animal system; and (3) reconstruction of architectural ideas by model making based on plant and animal systems.

The inquiry method was carried out exploratively; following the implementation of the design studio, observations, and data collection periodically from the process of learning up to the exhibition. Students collected a logbook as a report on the implementation of each stage of the project. This logbook was used as material for tracing various methods and results of students' exploration. Logbooks related to various strategies for exploring hidden knowledge of plants and animals were elaborated as a basis for understanding student rules in the deconstruction process. All the rules compiled by students based on the results of deconstruction were recorded. Then, rules and keywords were developed to become an architectural form as a reconstruction process. Reconstruction at this stage was done starting by making the basic model, complex model, and up to the final model.

The documentation, such as photos, videos, and logbooks, was collected based on the project stages. The results of the data were then catalogued based on the students' exploration method where this process requires the sensitivity of the researcher to read the results. This research is a qualitative method because it requires an interpretation in reading the data results (Creswell, 2009; Wang & Groat, 2013). The data catalogue was exploratively analysed to read the various hidden systems of nature as part of constructing the architectural form, followed by exploring the various methods carried out by students in detail within the process of deconstructing and reconstructing plant and animal objects.

Learning method

The pedagogical method used in this Basic Design studio consists of a series of lectures, workshops, exercises, and interactive activities; while the exploring method is carried out through redrawing, sketching, tracing, diagramming, and making models. These methods can encourage students to synthesise and transfer learning in architectural design (Datey, 2023). The studio begins with a study of deconstruction, specifically exploring hidden systems of plants and animal objects. This article is structured as the findings of the learning process of deconstructing and reconstructing the natural system of plants and animals through collecting and cataloguing the results of exploration carried out by students based on project stages. This article then signifies the various ways of deconstructing natural plant and animal systems to uncover hidden knowledge within.

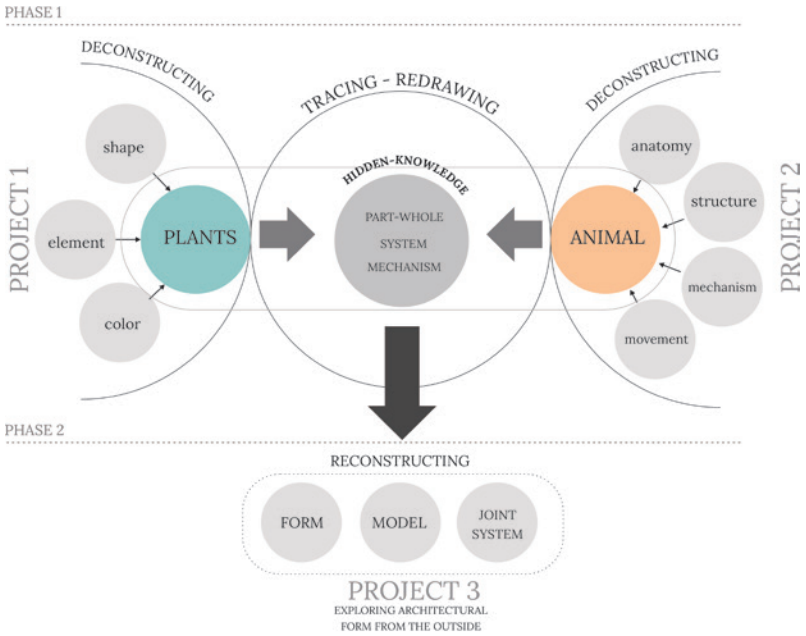

Figure 1. Learning process diagrams (Image by authors)

The studio implementation method was carried out by giving the same brief to students, but in the deconstruction procedure, students were free to use any method. In the brief, it was stated that students could use the tracing method, redrawing, and then compile their deconstructed system in catalogues and diagrams. A detailed explanation of the method selection was not specified, instead, students were trained to find their own exploratory method.

The learning process attempts to explore various methods of system-based architecture deconstruction and reconstruction of plants and animals. Logbooks related to various strategies for exploring hidden knowledge of plants and animals were used as a basis for understanding the rules in the deconstruction process developed by students. After that, the process of development of architectural form based on the rules was observed. This paper tries to contribute to the learning process of architectural design based on systems of nature as hidden knowledge, not as a metaphor for nature.

Learning strategies

The Basic Design studio began with an explanation of the project that will be carried out in three consecutive projects. Students were equipped with various perspectives related to architecture and nature, especially understanding how nature exists as hidden knowledge. This studio was divided into 13 groups, with each group containing between 11 to 12 students. Each group may freely choose their nature objects. As explained above, this studio consists of three projects. Projects 1 and 2 are part of the object deconstruction process which are (1) the deconstruction of the plant system and (2) the deconstruction of the animal system; while the third project is a reconstruction process through (3) making models based on plant and animal systems.

The learning process in this studio uses the terms deconstruction and reconstruction which means the process of 'disassembling' and 'assembling' the system to construct architectural forms. Deconstruction is a dissembling process that focuses on exploring the various systems that construct the plants' and animals' objects. In this studio, the system referred to a set of things that work together as part of a mechanism or interconnection network that composes the plants or animals' objects. Such mechanisms enable a natural process that supports the system of plant and animal objects to work in the environment.

Deconstruction rules on reading the nature system

In the studio, the students were equipped with an initial understanding of typology which was not only about classifying forms and functions as simply and concisely as possible. The opposite typology can be seen as a way to understand the system and the construction of form is done through the process of reduction to find the essence that can be developed intelligently. This Basic Design studio project focuses on the notion of the first typology outlined by Vidler (1997) which proposes the return of architecture to its natural origins as a guiding principle, beyond the imitation of nature order itself.

In the first stage, students were asked to choose and explore the system of plants and the second stage is followed by selecting and exploring animals about their system. In the first stage, students demonstrated different considerations in choosing objects including flowers, leaves, fruit, vegetables, and stems. The same thing happened in stage two in determining the animals subjects where they tended to select animals that are close to everyday life to those that are difficult to find. The difference in the selection of natural objects indicates the complexity of the plant and animal systems to be deconstructed. This shows that nature in our environment is rich in knowledge that can be traced as a basis for the development of architectural knowledge. The series of projects carried out in the Basic Design studio shows that there are rules for the reading system's nature in relation to students' prior knowledge.

Understanding the anatomy of nature as a part-whole relationship

The students began by reading the various arrangement of selected nature objects and mapping out each part of the arrangement. Through the redrawing process carried out by most of the students, it was shown that this deconstruction process focused on the anatomical arrangement of objects. This process trained students' awareness towards the smallest system that composes objects to the relation between the object's systems. One of the examples is students who tried to choose flies as animal objects for deconstruction where the students redrew and photographed the flies carefully. Each part of the flies was redrawn, ensuring accuracy in deconstructing objects. Through the act of redrawing, the deconstruction process of natural objects becomes detailed. When a part of the overall system is missing, the object cannot be seen as a complete object. Figure 2 shows how the colours, textures, and shapes of a flower become readable through redrawing because in the process, the students focused on observing before starting to draw them in two-dimensional forms.

Figure 2. Example of deconstruction of plants drawings (Images by Miftahul Huda and Vania Husnun Nabila)

On the other hand, the process of understanding the anatomy of an object was done by separating the parts that compose the overall system of the object (Figure 3). The parts are separated manually based on initial observations. These parts were then given a label to see how the relationship between these parts composes the anatomical system of the object. The students were required to write some notes on the separated parts of the object to understand the form, function, and system of the whole object. These notes help the deconstruction process carried out by students by bringing up keywords that can later inform the process of redrawing the object. The process of taking measurements and giving dimensions to each part of the deconstructed object showed that the students must be critical, thorough, and sensitive to a natural object.

This stage shows that the deconstruction process enables understanding the anatomy of nature as a part-whole relationship. Objects are not only existed as visually visible objects but also as a series of parts arranged as a complete anatomical system. The redrawing process carried out at this stage showed how a

more detailed understanding of nature can be captured through visuals. In addition, the cataloguing stage of the parts of the anatomical system as a whole enables possibility of new forms in the system of nature's deconstruction process.

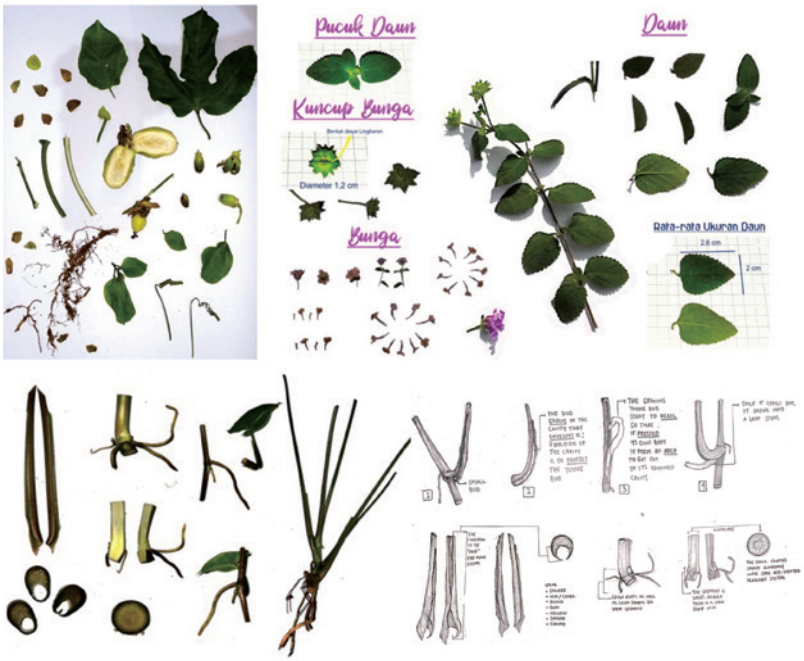

Figure 3. Example of the anatomy of plant drawings (Images by Ihza Rininta Ratna Palupi and Adelia Khansa Najla)

In the following stage, students were asked to focus on the mechanisms and materials as part of exploring the hidden knowledge that exists in the system of nature. This section trains students to observe objects not only through forms, functions, and systems but places more emphasis on the mechanisms and materials that enable the operation of the natural objects. At this stage, students were allowed to use additional information from various sources to sharpen the objects' deconstruction process.

Exploring the material and movement system of nature

In this stage, students deconstructed the objects to explore various systems, especially materials, structures, and forms through the tracing method. Focusing on the mechanism of movement and the mechanism of growth of plants and animals, in this part, the students can use various sources to research the selected objects of nature. The students use sources from books, journals, blogs, YouTube, and other digital information media. Utilising technology to enrich exploration in studio design is increasingly important (El-Mowafy & Hassan, 2023b).

Based on these digital sources, the students then trace the movement of objects and the details of every sequence. Tracing every movement that is performed by the nature objects requires critical thinking from students. Diagrams become an important tool to show the tracing results regarding object movement sequences. Repetition of observation is possible to explore the system of nature. Capturing movement and reading the objects' materiality needs to be done sequentially to develop the right understanding of the series of movement systems.

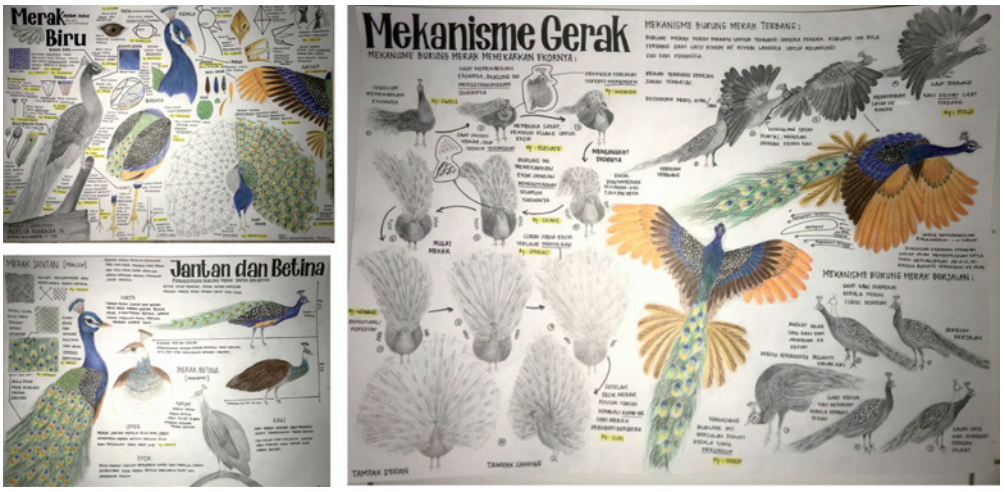

Figure 4. The peacock drawings (Images by Adelia Khansa Najla)

Figure 4 shows a student's explorations toward the movement of peacocks by tracing every part of the object's body multiple times with its changes of movement. The uniqueness of the peacock is its tail in which its system will be explored further. The focus of observation is not only on one part of the body but also on the movement of the tail in relation to the whole body, demonstrating the movement mechanism of the whole body system. The student further found that the material that makes up the object's body greatly influences its motion system. Light materials allow the animals to move easily compared to stiff materials. Peacock feathers can open and close depending on their movements. The students' explorations were focused on the peacock's three movements which are flying, walking, and showing off its tail. The three movements were recorded one by one to find the mechanism of the open-close peacock's tail, following the overall shape of the body.

Figure 5. The resplendent quetzal (Pharomacrus mocinno) movement drawings (Images by Ahmad Zaydan Al Ghani)

Explorations on the mechanism of the movement of other animals can be seen in Figure 5 which highlights variations of the movement of the bird from inside the cage. This student explored the object in detail by observing how the grip system works when it lands through the mechanism of the claws, tracing the movement of the wings when flying with various movements, and also tracing the movement of the pigeon's feathers. It was found through the traced drawings that there is a repetition of body ratio that supports the movement of the bird.

Figure 6. The streaked weaver tracing drawings (Images by Muhammad Fatikh Ulya)

Other students explored the construction process of a bird's nest (Figure 6). In building their nests, the birds perform a series of movements that can be recorded with a focus on the systemic rules of building the nest. Figure 6 shows the traced drawings with annotated keywords that define the nest-weaving sequence performed by the birds. In this case, the natural structural system can be found by tracing each process. The act of tracing in exploring natural systems demonstrates abilities to define the repetitive movement systems, form and matter, as well as relevant natural structures. The natural systems beyond their physical form and their changes throughout the time that were initially hidden can be made explicit. This stage emphasises the importance of time in exploring natural systems, especially those related to movement.

Reconstructing the natural system into architectural form

The project studio continues with the practice of 'making' three-dimensional models as possible architectural forms arranged based on the keywords resulting from the deconstruction of plant and animal systems. In developing their

model, the students selected keywords from either plants or animal explorations to be used in making abstraction. Model development will be carried out in several stages to develop the complexity of the model gradually. Model workshops related to model-making and materiality were carried out to provide basic knowledge for students in making architectural form models. Students are given the freedom to determine the models' materials that are appropriate for their chosen keywords.

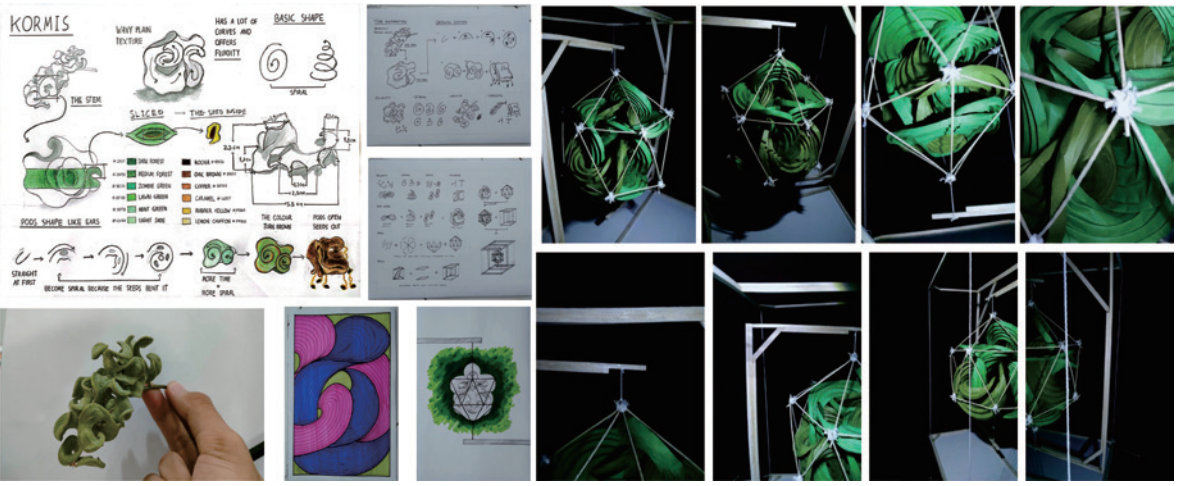

Figure 7. The development model based on the cornice plant (Images and photographs by Dhika Fanhari)

In the model-making process, students were asked to work individually by generating possibilities on how the selected keywords can be used as a starting point in shaping the three-dimensional model. Figure 7 illustrates one of the students' making processes using the keywords 'flexibility' and 'repetition' obtained from the process of deconstructing the cornice plant. The student chose to use paper to demonstrate the flexibility keyword. In the process, several obstacles occurred, including the inability of ivory material to show the quality of vibration which is one of the characteristics of flexibility. Follow-up experiments were carried out using wire material to show some flexibility as well as repetitively producing vibration as required from the natural systems.

After the exploration and selection of the material, the student was asked to make several possibilities for the reconstruction process. This process started through a diagram that will help conceptualise the three-dimensional model. The diagram was made by developing keywords that can be read in three dimensions. After a diagram that explains the keywords was established, the reconstruction process of the model was carried out by starting to apply all the results of the exploration in the form of materials, shapes, and connections to the context as the basis of the hidden knowledge of plants and animals. The three-dimensional shape of the natural system should include context as part of its consideration. In the case of the peacock's tail system, the context was defined by opening wider on one side which informed the system of nature. The models show a unity between the context and the development of keywords in driving the architectural form.

Figure 8. The development model of a streaked weaver nest (Images and photographs by Muhammad Fatikh Ulya)

The method of three-dimensional model-making as possible architectural forms based on keywords was derived from the deconstruction of plant and animal systems that were informed by natural objects' (1) anatomical systems; (2) movement systems; and (3) growth systems. Figure 8 shows the catalogue of the model-making process carried out in Project 3. The idea of model development by thinking about context as a whole system shows that learning about context and form cannot be separated. From the process of making three-dimensional models based on the deconstructed system of nature, it is understood that the nature learning model drives sensitivity in exploring the nature system as a hidden knowledge.

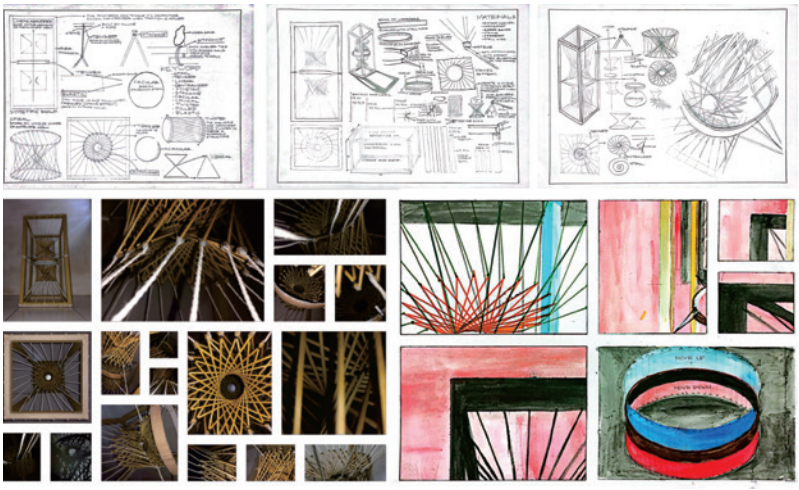

Figure 9. The development models of antelope and Syngonium stem (Images and photographs by Ditho Arthur Febrianto)

Presenting an architectural form based on the hidden knowledge of nature system

As a conclusion, this study has demonstrated an architectural design learning method that explores nature systems rather than simply adopting its form as the basis for architectural form development. This article describes the implementation of learning processes that enable sensitivity in reading various hidden knowledge in natural objects through the act of redrawing, tracing, and cataloguing. Detailed readings of the

parts that construct the overall system show how a part-to-whole system of plant and animal objects was determined by the rules of nature. The study also shows that learning from nature is beneficial in acquiring initial knowledge of understanding architecture, especially related to form and function.

The outputs of the Basic Design studio project presented in this article demonstrate how the development of architectural forms through rules, keywords, and mechanisms from nature's system can be richer than just imitating the physical form of nature. One rule of nature can be reconstructed into various architectural forms. The learning results show the importance of sensitivity to nature which builds the understanding and skills to reveal how natural objects have hidden knowledge that deeply enriches forms generation as an important part of the architectural design process.

Acknowledgements

The students' works presented in this paper are gathered from the Trimatra 1 Studio at Universitas Diponegoro in 2022-2023 under the coordination of Resza Riskiyanto and Arnis Rochma Harani. This research was financially supported by Strategic Grant 2023 from the Faculty of Engineering, Universitas Diponegoro.

References

Abusafieh, S. F. (2022). An interdisciplinary reflective approach to promote architectural design pedagogy: Animating basic design principles by music visualizer. *Open House International*, 47(4), 638–656. https://doi.org/10.1108/OHI-04-2022-0108

Ball, P. (2009a). *Shapes: Nature's patterns: A tapestry in three parts*. Oxford University Press.

Ball, P. (2009b). *Branches: Nature's patterns: A tapestry in three parts*. Oxford university press.

Creswell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed). Sage Publications.measures of well-being attenuates well-being's association with individualism. *Asian Journal of Social Psychology*, 22(3), 256–267. https://doi.org/10.1111/ajsp.12364

Datey, A. (2023). Decolonising the design curriculum: Making "sustainability" accessible, understandable and practicable to second-year undergraduate architecture students. Archnet-IJAR: *International Journal of Architectural Research*. https://doi.org/10.1108/ARCH-10-2022-0228

El-Mowafy, B. N., & Hassan, A. M. (2023a). A problem and project-based learning strategy to promote students' motivation in post-pandemic graduation design studio: A prospective comparative study. In A. E. Hassanien, V. Snášel, M. Tang, T.-W. Sung, & K.-C. Chang (Eds.), *Proceedings of the 8th International Conference on Advanced Intelligent Systems and Informatics 2022* (Vol. 152, pp. 89–106). Springer International Publishing. https://doi.org/10.1007/978-3-031-20601-6_8

El-Mowafy, B. N., & Hassan, A. M. (2023b). Post-pandemic adopted learning approach to promote architectural education: Statistical approach. *Higher Education, Skills and Work-Based Learning*. https://doi.org/10.1108/HESWBL-05-2022-0099

Forty, A. (2000). *Words and buildings: A vocabulary of modern architecture*. Thames & Hudson.

Lee, S. (2012). A site from seen to contextualized: Urban place in Busan, South Korea. *Journal of Urban Design*, 17(4), 533–548. https://doi.org/10.1080/13574809.2012.706363

Moosavi, S. (2022). Design experimentation for nature-based Solutions: Towards a definition and taxonomy. *Environmental Science & Policy*, 138, 149–161. https://doi.org/10.1016/j.envsci.2022.10.004

Park, E. J., Lee, K., & Kang, E. (2023). The impact of research and representation of site analysis for creative design approach in architectural design studio. *Thinking Skills and Creativity*, 48(101271). https://doi.org/10.1016/j.tsc.2023.101271

Pioz, J. (2014). Learning from nature as a tool for innovation in architecture. *Engineering for Progress, Nature, and People*, 3142–3149. https://doi.org/10.2749/222137814814069967

Saghafi, M. R. (2021). Teaching strategies for linking knowledge acquisition and application in the architectural design studio. *Archnet-IJAR: International Journal of Architectural Research*, 15(2), 401–415. https://doi.org/10.1108/ARCH-01-2020-0005

Suryantini, R., Saginatari, D. P., & Yatmo, Y. A. (2022). Deep interior: Sensorial encounters of Orang Suku Laut with the sea. *Interiority*, 5(2), 197–216. https://doi.org/10.7454/in.v5i2.232

Vidler, A. (1977). *The third typology. Oppositions 7*. Princeton Architectural Press.

Vidler, A. (2013). *The third typology and other essays*. Seaforth Publishing.

Wang, D., & Groat, L. N. (2013). *Architectural research methods* (2nd ed.). Wiley.