Biomimicry Learning
as Inspiration for Product Design Innovation
in Industrial Revolution 4.0

Dina Lestari
Product Design Study Program, Universitas Agung Podomoro (Podomoro University)
E-mail: dina.lestari@podomorouniversity.ac.id

ABSTRACT
Nature can be a source of unlimited inspiration, biomimicry is an innovative approach to find sustainable solutions to overcome problems and meet human needs by imitating existing patterns and strategies in nature. The Industrial Revolution 4.0 brought many changes in human life, changes in lifestyles, ways of working, ways of learning, and ways of communicating between humans in many aspects. Most University students make use of technology to find and develop their ideas especially in creative industries where the OIM (Observe, Imitate, Modify) practice can be done through the Internet by observing from another researcher's observation. While biomimicry offers researchers to observe nature and create technology innovation inspired by nature. Students need to experience and learn from nature and use technology wisely. This study examines the biomimicry-inspired works of Product Design undergraduate program students of Podomoro University Jakarta. The methodology research that we use in this study is a qualitative participatory method with comparative and correlational studies. The content of this study is to learn and evaluate the process and result of student's biomimicry observation into innovative product design. The conclusion can also be drawn that comparing the different levels of students which is the first year, second year, and third-year students by using the biomimicry observation approach will show variated concepts and skills on their work depending on what knowledge that they have learned from each semester.

Keywords: learning, biomimicry, inspiration, innovation, product design, industrial revolution 4.0

Pembelajaran Biomimikri sebagai Inspirasi dalam Inovasi Desain Produk di Era Revolusi Industri 4.0
ABSTRAK
Alam dapat menjadi sumber inspirasi tanpa batas, biomimikri adalah pendekatan inovatif untuk menemukan solusi berkelanjutan untuk mengatasi berbagai permasalahan dan memenuhi kebutuhan manusia dengan meniru pola serta strategi yang nyata di alam. Revolusi Industri 4.0 membawa banyak perubahan dalam kehidupan manusia, perubahan gaya hidup, cara bekerja, cara belajar, dan cara berkomunikasi antara manusia dalam banyak aspek. Sebagian besar mahasiswa memanfaatkan teknologi untuk menemukan dan mengembangkan ide-ide mereka terutama di industri kreatif di mana praktik ATM (Amati, Tiru, Modifikasi) dapat dilakukan melalui Internet dengan mengamati dari pengamatan peneliti lain. Sementara biomimikri menawarkan peneliti untuk mengamati alam dan menciptakan inovasi teknologi yang terinspirasi oleh alam. Diharapkan

dengan riset ini siswa bisa mendapatkan pengalaman nyata, mereka dapat termotivasi untuk mempelajari alam dan juga dapat menggunakan teknologi secara bijaksana. Riset ini bertujuan untuk mengkaji karya-karya yang terinspirasi biomimikri dari mahasiswa program sarjana jurusan Desain Produk Universitas Agung Podomoro Jakarta. Metodologi penelitian yang digunakan dalam riset ini adalah metode kualitatif parsitipatif dengan pendekatan korelatif serta komparatif. Konten kajian dalam studi ini merupakan evaluasi serta proses pembelajaran mahasiswa dalam penciptaan desain produk inovatif. Dari hasil riset ini dapat ditarik kesimpulan bahwa ternyata setelah melakukan perbandingan rancangan mahasiswa tahun pertama, kedua dan ketiga dengan menggunakan pendekatan observasi biomimikri maka ditemukan adanya perbedaan hasil serta tingkat keterampilan pada masing-masing angkatan tergantung dari pengetahuan yang mereka telah pelajari dan dapatkan di setiap semesternya.

Kata Kunci: *pembelajaran, biomimikri, inspirasi, inovasi, desain produk, revolusi industri 4.0*

INTRODUCTION

"Man differs from other animals particularly in this, that he is imitative, and acquires his rudiments of knowledge in this way; besides, the delight in imitation is universal." That is a famous quote from Aristotle, and in his article "Poetica" he explains that human is as always intuitively learning by imitating since they were born in this world. People learn to survive by imitating various things such as how to express, eat, walk, move, behave, and various things from their surroundings. By mimicking, humans pass through the process of exploration, observation, and experimentation to solve problems and fulfil their needs (data source: http://classics.mit.edu//Aristotle/poetics.html).

The Industrial Revolution 4.0 brought many changes in human life, changes in lifestyles, ways of working, ways of learning, and ways of communicating between humans in many aspects. Technology has been argued as giving a positive influence on people's way of thinking. Steve Johnson (2005) in his book "Everything Bad is Good for You", he stated that technology making people smarter by obtaining, interpreting, and processing data and information from many sources (Johnson, S., 2006). Many researchers have observed how technology giving impacts on our brains and affects the way how we think and perform.

Observation is a very important step for researchers to create reality. An observer role is to expose the virtual potential of their research objects, for example, if humans are a machine or computer, so the input of audio and visual information is needed and then processed through observation and projected in a reality. The visualized reality can be shown in a variated form such as art, writing, movement, or even music. The results of observations can also vary depending on the empirical experience of each observer. Through deep experience, an object that was

previously considered insignificant will have its potential explored and become an internal part based on the observer's empirical experience. There are several ways of observing, for example by the help of technology or by doing a holistic approach. Technology will help people collect data and information instantly, while deep observation by experience needs time and process but everything has its pluses and minuses.

Prime Minister of India Narendra Modi once said that both learnings from experience and learning from education are important. It is from education & values people can determine how they can learn from experience (Prime Minister of India Narendra Modi speech at the commemoration of teacher's day at the Manekshaw Auditorium, New Delhi on 5 September 2014).

Experience-based learning was also popularized by David Kolb, a professor and education expert in the field of experience-based learning. The learning method that he developed is known as the Experiential Learning Model (ELM). David Kolb believes that learning is the process by which knowledge is created through the transformation of experience. Knowledge is produced from the merging of captured and transformed experiences.

Kolb stated that "Experiential Learning is a learning process, a process of change that uses experience as a teaching or learning medium that does not only utilize material sourced from theories in reference books or from instructors" (Kolb, A. Y., & Kolb, D.A., 2005:194). According to Kolb's Experiential Learning Model, there are 4 elements of experiential learning which is concrete experience, reflective observation, abstract conceptualization and active experimentation.

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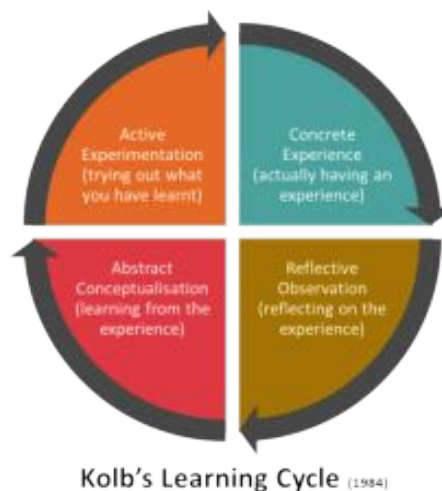
Figure 1. Kolb's Experiential Learning Model
Source: https://www.inspiring

In a study conducted by Ni Wayan Rina regarding the effect of learning with experiential methods on students 'critical thinking skills, she stated that experiential learning affected students' ability to think critically (Lestari, N. W. Dkk, 2014). Then there are also the results of research carried out by Anggara and Komang, according to them the experiential learning method is quite relevant to be implemented as an effort to develop self-concept and concept understanding (Anggara, Ari & I Komang, 2012).

Students need to experience and learn from nature and use technology wisely. This research examines the biomimicry-inspired works of Product Design undergraduate program students of Podomoro University Jakarta. The methodology research that we use in this study is a qualitative descriptive method with comparative and correlational studies. The content of this study is to learn and evaluate the process and result of students' biomimicry observation into innovative product design.

Designing with Technology:

Technology helps improve better education by facilitating the learning process, It can connect people that separated by distance, time, and place. People can browse for information, data, and finding inspiration from all over the globe by learning through the internet. People learn through observing other people's behavior, attitudes, and then the outcomes of those behaviors (Bandura, A., 1977). "Most human behavior is learned observationally through modelling: from observing others, one forms an idea of how new behaviors are performed, and on later occasions, this coded information serves as a guide for action." (Bandura). This Observing, Imitating, and Modelling theory is one of social learning theory from Bandura. Bandura explains how human behaviors influenced by continuous reciprocal interaction between cognitive, behavioral, and environmental aspects. Imitating is human nature and in this digital era, imitation behavior evolves with the help of technology. Technology provides abundant information and data to be observed and learned as a model.

For a designer, exploring inspiration is an important stage in making a design. With the help of technology, the process of exploring inspiration becomes easier. According to Bandura's social theory, human nature is to copy and it includes the habits of Observing, Imitating, and Modeling, and now for many designers in this digital era, those term seems to change into Observing, Imitating and Modified. We may have heard the words "There is nothing new under the sun" This practice has been used by most designers to recreate designs.

In this digital era, designers surfing on the internets for inspiration. Inspiration is obtained by browsing on a design portal in search of design references. Some pages that are often referred by designers include Pinterest, Fast

Co. Design, Solid Smack, Inhabitat, Kick Starter, Core 77, Behance, Design Taxi, and many more. Existing works or designs are observed and then part of the design is taken to be imitated and then modified to produce new work or product. This then becomes common practice, the observation process becomes easier and instant. But the problem is if designers depend entirely only on technology, in this case, internet, then it will be a matter of time until they deal with technical and ethical issues of designing by taking inspiration from the internet only, which is why special skills are needed in creating personal and original designs.

Table 1. Designers Inspirational Blogs (Pict source: Links below)

DESIGNERS INSPIRATIONAL BLOGS

No	Websites	Links
1.	**Pinterest**	https://id.pinterest.com/
2.	**Fast Co. Design**	https://www.fastcompany.com/co-design
4.	**Inhabitat**	https://inhabitat.com/

5. **Kick Starter**

https://www.kickstarter.com/
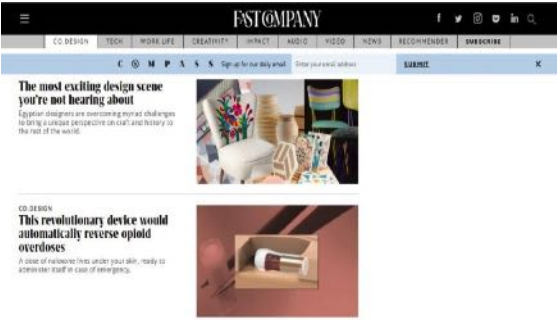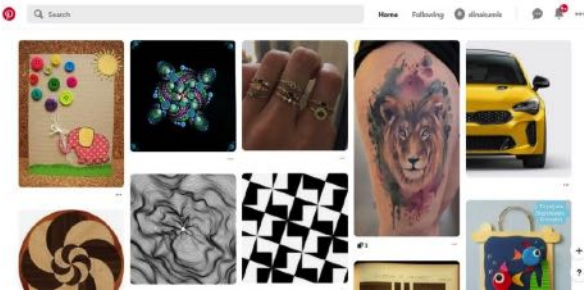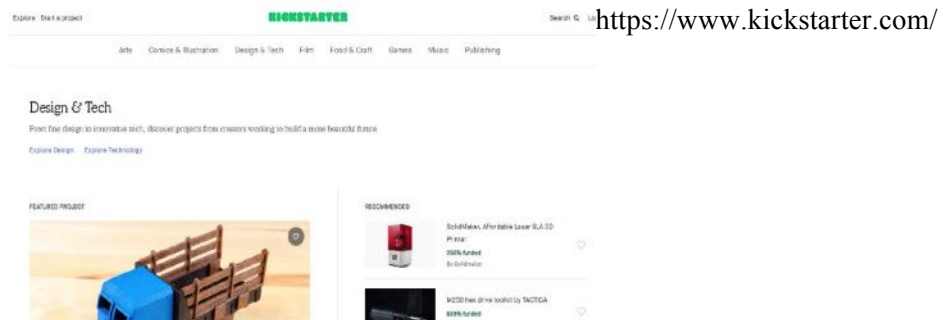
6. And Many More...

In the design school, creating design has rules, stages, and processes. And the process is part of learning so that the prospective designers not only rely on technology but also hone their exploration and in-depth observation capabilities. Technology is a tool created by humans to help humans solve problems and meet human needs.

Design Thinking for Design Students:

In design education institutions, students as academics are required to pass several processes on designing based on rules, one of the design principles that are often used in designing is design thinking theory from Stanford Design School.
An effective way to design products is by using a design thinking framework, this framework refers to how to solve problems that focus on humans through analysis or observation of needs.
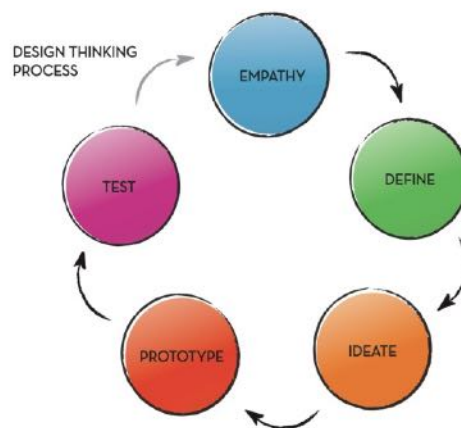
Figure 2. Design Thinking Process
Source: https://dschool-old.stanford.edu/groups/k12/wiki/6c04c/Visual_Resources.html

According to Baeck & Grimmett, design thinking is a creative approach that focuses on ways to solve problems and user needs with a more experimental approach (Baeck, A., Gremett P, 2011). In his book The Science of the Artificial, Simon defines an initial model of the design process, that consists of seven stages which are defined, research, ideate, prototype, choose, implement, and learn. (Simon, Herbert Alexander, 1996). Down below is a process of design thinking based on human needs from Stanford Design School that has been used in the process of making products by several numbers of students in the Product Design Program at Podomoro University:

1. Empathy
   Empathy is a fairly important stage in the design thinking process, in this stage, the designer is asked to jump right in and recognize the problem from the user's perspective. Observing needs in the user's physical environment to gain personal experience and find problems based on empathy.

2. Define
   At the stage of the definition, the data that has been collected from the process of observation (empathy) is then analyzed and synthesized.

3. Ideate
   After the problem is analyzed, the next step is to find a solution by having a brainstorming method and try to think creatively "out of the box" to generate as many ideas as possible (expand the solution space).

4. Prototype
   This stage is experimental, ideas that are suitable then visualized in the form of prototypes as product samples.

5. Test
   This stage is the testing stage of the prototypes, the sample products then tested for their durability, ergonomics, and conformity based on the needs of consumers.

Ideas in creating an innovative product can be explored with in-depth observations, one of the ways to explore innovative ideas in observing is by empathizing, not only empathizing with humans but also the surrounding environment, plants, animals and even the universe. To deal with the global ecological crisis that is happening in this era, humans need to change attitudes and mindsets by empathizing with nature. Humans also need to study nature more deeply to be able to control and use it wisely.

Biomimicry As Innovation Inspiration:
Marcel Proust a french novelist stated a famous quote saying that the real voyage of discovery consists not in seeking new landscapes, but in having new eyes

(Marcel Proust, French novelist famous quotation (1871–1922). Everything which looks common at first sight will reveal its potential through observation, everything that viewed from different perspectives will look different too.

The source of various kinds of innovation is "needs", humans are motivated to create inventions according to their needs. In the process of creation, in-depth observation is one of the most important steps. The object of observation can be obtained from the things around us from the simple to the most complex. Nature is a source of unlimited inspiration, that is why the exploration process on nature could support the creation of innovation based on the observation process.

Janine M Benyus in her book Innovation Inspired by nature explains Biomimicry or often also called biomimetics as an innovation process by observing nature. The observations focus in this process are every aspect of the natural elements, which are their visual form, their mechanism or their systems, and other natural elements to be imitated or used as inspiration as part of their purpose in overcoming human problems and needs (Benyus, Janine M., 1997:2). The term biomimicry itself is adapted from the Greek language bios, which means life, and mimesis, which means imitating. Other terms that are commonly used are bionics, bio-inspiration, and biognosis.

Biomimicry is a method of studying nature to create or develop sustainable solutions in overcoming human problems in the fields of engineering, material science, medicine, and other fields (Mueller, T., 2008). The aim is to create a new product, process and policy system that is adapted to live on earth in the long run. There are 3 types of biomimicry - the first is to take inspiration from its visual form, the second is to imitate the process of occurrence and the third is to imitate at the ecosystem level, such as building systems inspired by nature.

Nature is the greatest teacher, Filiv Tafsan and Elif Sonmez said that science; from nature to model, measure, and mentor, taking a lot to learn. Biomimicry examined models in nature, then imitating these designs or taking inspiration from them which aims to provide solutions to people's problems are one of the new branches of science (Tavsan, F., & Sonmez, E., 2015).
Elena Lurie - Luke wrote in her article "What can Biomimicry Inspire" she said that Biomimicry has revealed new opportunities for material development across a range of fields, including optics, medicine, agriculture, energy generation, textiles, transport aids, and construction. Fully exploiting the range of structures on offer in nature presents the unique opportunity to utilize our environment in a new, safe, and environmentally-sustainable manner (Lurie-luke, E. (2014).

Actually, the design process by taking inspiration from nature has long been applied by an artist who is also an Italian-born Innovator, Leonardo Da Vinci. Some of his designs took inspiration from nature and then decades after that, it was developed by scientists and became part of the latest technology. For example,

Leonardo was the first inventor of the design of war tanks, he was inspired by the turtle shell self-defense mechanism. Then by studying the anatomy of the bird's wings, Leonardo tried to design flying vehicles. Leonardo has created technology by taking inspiration from nature (Da Vinci's Tank: A War Machine for the Duke of Milan. Davincilife.com.)

Figure 3. Leonardo Da Vinci Nature Inspired Invention
Source: https://www.davincilife.com/davincis-tank.html

Even though technology has grown and developed, it does not mean that humans no longer need nature as an inspiration for designing products. Nature becomes a powerful tool in creating technology. For example, Eiji Nakatsu is the head of the Shinkansen railroad project who also works as a bird watcher. He studied the bird's anatomy and behavior to develop shinkansen railroad technology. Nakatsu designed the front end of the train with a beak model of kingfishers and penguins, this bird can dive from air to water with a little spark to catch fish. With this visual form, the train design result is not only reducing the sounds so that it becomes quieter, but also uses 15% less electricity, even the train is also able to run 10% faster. (Source: https://biomimicry.org accessed May 14, 2019). Shinkansen trains are only a small example of the application of biomimicry on technology, there are still many other natural elements that can be used as inspiration to create and develop other innovative products (Source: christophe.haubursin@vox.com (Documenter Video).
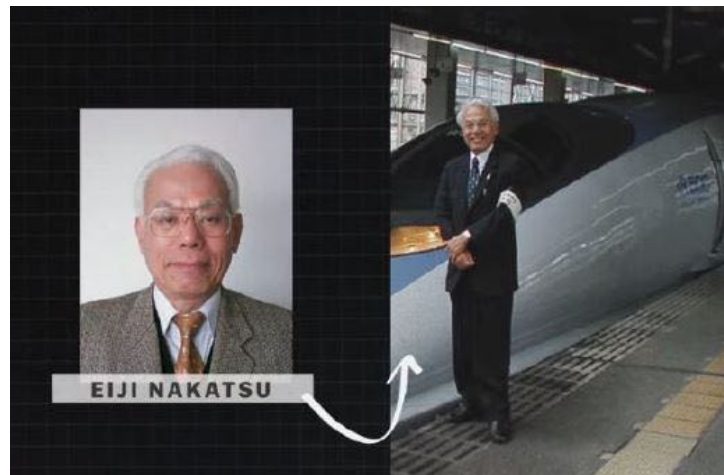
Figure 4. Shinkansen Train Design by Eiji Nakatsu
Source: christophe.haubursin@vox.com

This paper is an evaluation report of the research about the application of biomimicry learning to product design students. In this project, students use the design thinking approach. The subjects in this study were students of the product design study program at Agung Podomoro University. The methodology used in this research is a descriptive qualitative method with comparative and correlational studies.

RESEARCH METHODS

The method used in this research is a qualitative method with a participatory approach. Students are involved as the main actors so the impact of experiential learning can be estimated based on student contributions through the activities they do. According to Lexy J Moleoung in his writing titled "Qualitative Research Methods" what is meant by qualitative research is research that seeks to understand a phenomenon experienced by research subjects and can manifest behavior patterns, perspectives, motivations, actions, and so on holistically (Moleong, Lexy J, 2005). The data collection can be done using descriptions and in the form of words and language. In a particular context that is natural and also utilizes a variety of natural methods. Based on the opinion of Nazir in Research Methods (2005:58) comparative research is one of the descriptive studies aimed at finding fundamental answers about causation, this research was conducted by analyzing the indications of causation or also the trigger for the emergence of certain phenomena (Nazir, Moh., 2005).

This research involving design students as a participant, this practice meant to motivate design students to engage in nature as one of their source of inspiration. Quoted from DeKay writings in "Systems Thinking as the Basis for Ecological Design Education". He mentioned that to educate designers for ecologically and

socially responsible practice, design schools need to be radically redesigned in their structure, content, and methods (DeKay, M., 1996).

Just like Yeler's opinion in his article "Creating Nature Awareness in Design Education". He said that each student can gain awareness of nature and transform formations in nature and biological expressions into design knowledge if education programs are revised in a way that enables the student to comprehend how these events occur in nature. It is assumed that in design courses, which constitute a gradual process, learning knowledge of nature by exploration, analyzing this knowledge, making accurate determinations, and transforming knowledge of nature into design knowledge by making connections will increase the creativity of design students. In this context, including nature-inspired design approaches in education programs of all design disciplines are prioritized in means of creating a sustainable world (Yeler, G. M., 2015).

The sample examined in this research were students of the Agung Podomoro University product design study program. As a comparison sample that was taken is students from 3 different levels, next is the list of the sample criteria.

Sample Criteria:
- Sample taken is students of the first batch of product design program in the 5th semester, the 2nd batch in the 3rd semester and the 3rd batch in the 1st semester.
- Each batch is taken 2 samples as a comparison.
- The design output for each batch will be compared with another batch.
- Students that taken as the sample is the one that having nature as inspiration in their design or their products, whether it's inspired by the nature visuals shapes, mechanisms or ecosystems.

Figure 5. Nature Inspired Observation Process
Source: Private picture

In the next table, 6 students taken as samples. (2 students from semester 1, 2 students from semester 3 and 2 students from semester 5). This is the list of the student's samples:

Table 2. Students List (Nature-Inspired Product Design)

No	Students Initial	Join Year	Batch	Semester
1.	B.N	2018	3	1
2.	N.G	2018	3	1
3.	A.F	2017	2	3
4.	Y.A.S	2017	2	3
5.	B.F.N.W	2016	1	5
6.	J.S	2016	1	5

Some of these students make product designs based on the research of nature, they make observations to get inspiration for the products they design, but it turns out that the output result from each batch is different. The difference is shown in the outcome of the design they created and it turned out to have influence based on the background of the provision of knowledge given to them each semester. The following table is a list of the research results using the biomimicry approach.

Table 3. Students Design (1st Semester/Join Year 2018)

Student Initial: B.N

Product Visualization: Bird Chair Design Sketch.

Nature Inspiration: Sparrow	**Product Design**

Note:

Inspired by the sparrow, the anatomical shape of the bird's body is the inspiration for the reclining system on the back of the lounge chair. Indications of creation are still focused on a visual shape on the bird as a source of inspiration, due to limited knowledge of materials and the production process, the outcome is still

limited to a design sketch, whereas for the creation of the prototype it cannot be done yet.
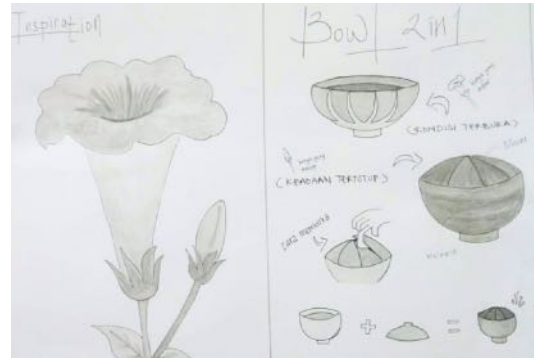
Student Initial: N.G

Product Visualization: Flower Bowl Design Sketch

Nature Inspiration: Japanese Frangipani Flower	**Product Design**

Note:

The inspiration that is taken in this design is from the Japanese frangipani flower, she took the open-close system of the Japanese frangipani flower petals as inspiration. She designs a silicone bowl that can be opened or closed just like the mechanism of Japanese frangipani petals. Indications of creation are still focused on visual innovation as a source of inspiration, due to limited knowledge of materials and the production process. the outcome is still limited to a design sketch.

Table 4. Students Design (3rd Semester/Join Year 2017)

Student Initial: A.F

Product Visualization: Water Splash Table Lamp

Nature Inspiration: Water Splash	**Product Design**

Note:

The inspiration that is taken in this work is from the water splashes, students in this semester have received knowledge about material and process in product making. This student observing the visual character of water by replacing it with resin material.

Student Initial: Y.A.S
Product Visualization: Table Lamp.

Nature Inspiration: Awan.	**Product Design**

Note:

The inspiration that is taken in this work is from the visual shape of clouds, students in this semester already acquired knowledge about material and process in product making. This student observing the visual character and the movement of clouds. He chooses luminous fabric and wire to copy the movement of clouds.

Table 5. Students Design (5th Semester/Join Year 2016)

Student Initial: B.F.N.W

Product Visualization: Beach Reclining Seat

Nature Inspiration: Nature Ecosystem (Beach)   **Product Design**

Note:

The inspiration that is taken in this work is from the ecosystem of the beach, the dynamic movements of beach waves and elements of coconut trees which can be found growing on many beaches were taken partially for his product inspiration. Students in this semester already acquired knowledge about designing furniture as well as material and process in product making. After this student studying nature element and movement on the beach, he designs a beach chair prototype by using synthetic rattan materials.

Student Initial: J.S

Product Visualization: Rocking Sofa

Nature Inspiration: Peanut Shell   **Product Design**

Note:
The inspiration that is taken in this work is from the shell of peanut, students in this semester already acquired knowledge about designing furniture as well as material and process in product making. Peanut shell shape deformation was taken as inspiration to create a rocking sofa by using synthetic rattan materials.

CONCLUSION

Base In the comparative study above, we see a different outcome and it's indicated from different weighting courses that have been given to them each semester. The more advanced courses they get each semester, the more they could create a better and tangible design on their products. The following is the list of courses given to students each semester.

Down below is the list of courses for students from the first semester:
1. Design Presentation
2. Process and Material
3. Introduction to Product Design
4. Science and Technology (Applied Mechanics, Calculus, Physic, and Technical Math)
5. General Courses such as Religion and Indonesian Language.
6. Special Courses TAEL (Thinking and Acting like Entrepreneurial Leader).

Down below is the list of courses for students from the third semester, they have taken all the courses above on the first semester and at third semester they learn the following courses:
1. Digital modelling 1 dan 2.
2. Design Thinking.
3. Research Methods.
4. Design Management
5. Interaction Design.
6. Ergonomics.
7. General Courses (Pancasila dan Citizenship).
8. Special Courses CTPS (Creative Thinking and The Power of Simplicity).

Down below is the list of courses for students from the fifth semester, they have taken all the courses above in the first and third semesters. On fifth semester they learn the following courses:
1. Furniture Design
2. Modeling Workshop.
3. Colloquium

4. Packaging Design
5. Innovation Design

From the list above, we could identify the different outcomes of students' design by comparing the list of the given courses. The more knowledge they get the better the quality of the products they produce. Biomimicry learning is quite useful to be applied to Product Design Innovation. As Gardner says that Biomimicry learning could encourage students to go out from their comfort zone and so that they can learn to integrate other scientific disciplines to see how they can draw a common thread when applied in design projects and technological innovations (Gardner, G. E. (2012). From this student's nature-inspired work we could see how nature could influence the visual form of their product, but to deepen the biomimicry aspect on innovation, design students need to integrate other scientific disciplines to enrich and wider their view on getting inspiration from nature. That is why it is necessary to do a collaborative project with interdisciplinary institutions as an effort to improve this biomimicry innovation research, and that could be our next project.

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