ATLANTIS PRESS
Advances in Social Science, Education and Humanities Research, volume 502
Proceedings of the International Conference of Innovation in Media and Visual Design (IMDES 2020)

Eco-Design Strategy Within Design Thinking Framework for Children's Furniture at Lentera Harapan School Rote, NTT: A Case Study

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ABSTRACT
Product designers have an important role to play in the field of eco-design due to their position at the initial stage of the product development process (PDP) where the design brief is the most important decision to be taken. The aim of this paper is to develop a framework to guide designers in integrating eco-design strategies within the framework of design thinking. Building on the Stanford Design Thinking Framework, a list of product design strategies is put in place to achieve better eco-design outcomes. The framework is based on a case study designing children's furniture for the Lentera Harapan School in Rote. As Rote is far from the location of the designer. Eco-design strategies are appropriate for this project, as the design needs to be very efficient in order to compensate for the logistic effort needed to deliver the furniture to Rote. The results of the study are children's furniture designed for LSH Rote 's school, which incorporates eco-design strategies within the framework of design thinking. The furniture is efficient as each piece is standardized, the waste materials are used to make children's educational toys, the chair is stackable, and the table can be disassembled for efficient shipping. The furniture used by the MDF board and the metal frame, in which both materials can be repaired at the Rote workshop.

Keywords: *eco-design, design thinking, product design, children furniture.*

1. INTRODUCTION

Technology have developed human life in many aspects of life. The growth of human's population and wealth lead to consumerism and extract-buy-use-dispose lifestyle which cause highly damages to the environment. Within this environmental problem that is caused by product manufacturing, comes the term Design for Environment (DFE) or eco-design. Environmental and social problem increasingly seen by the industries as opportunities to foster business efficiency, encourage innovation, improve brand positioning, and enhance business communications. Eco-design has given quite a contribution by making a change on manufacturing to be more sustainable in the last decade.

To reduce environmental impact during manufacturing, product design has been identified as one of key strategies [1].

Eco-design

Eco-design is a broader concept that incorporates various sub-strategies to enhance the efficiency of environmental product performance. It is a product-centric view that focuses on the reduction and eradication of pollution, resource depletion and human health hazards during the manufacturing process [2]. Many products have become more sustainable by better design, for example by decreasing the sum of materials needed in production or energy consumption in use.

In the business context, there are many resource strategies can be used in eco-design consideration. The strategies aim to keep resources and products at their best value for as long as possible to prolong their life usage so that they can function for longer with the optimum experience. The first strategy is the "narrowing loop." It is about reducing the use of goods or services, increasing resource efficiency, and doing better with less, which can be a cost-saving opportunity. Reducing and material

efficiency should not compensate for durability, the aim is to be efficient while retaining the value and material of the product for as long as possible. Research showed that manufacturing durable products can add the number of resources needed for production, thus there is a trade-off between robustness and resource efficiency in manufacturing process. The best strategy to balance between durability and cost resource efficiency is to design products that are easy to repair, preserve, improve, refurbish and remanufacture. The extra resource and energy use in manufacturing process can be balanced by the longer usage of the product. On the other hand, to keep a product valuable, people should want to keep the products for long time Therefore, emotional design is key consideration as well while doing eco-design.

The second strategy is 'slowing loop,' developing a business model and value chains that can facilitate re-use over time, by designing long-term goods, extending the use of product life, and offering repair and remanufacturing services. These actions may prolong the use of product life and slow down the production of new products that need more resources and energy. The third strategy is to close the loop. After many cycles of reuse, the loop needs to be closed and recycled. Cradle to cradle is the act of separating the technical material from the biological material, so that the original form of the material can be used to produce the product [3]. Therefore, it is important not to mix materials, they are easier to recycle. Unfortunately, many products are mixed with different materials, such as fabric, so it's hard to recycle. Disassembly and reassembly are keys to closing the loop. Out of the three strategies outlined above, the "slowing loop" is the most difficult and important strategy. As the means in which the product is designed, manufactured, and used needs to be changed. By slowing down the loops, the amount of resources used in production can be reduced and the amount of waste generated that needs to be recycled can also be reduced.

Below are arguments made by previous research the benefits of adopting eco-design.

	Internal Drivers	**External Drivers**
Environmental	Reduce resource consumption	Comply with government environmental regulation
	Reduce environmental impact	Contribute to global sustainability
	Continuous improvement	
Economic	Variable Cost savings	Market difference
	Variable Cost reductions	Create new market who willing to pay premium price for eco-design product
	New market opportunities	Improve supply chain management system
	New product development	
	Increase product quality	
Social	Increase company's image	Environmental consciousness
	Increase innovation and entrepreneurship	Extended producer responsibility
	Increase worker motivation	

Source: [1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12],[13]

Previous researchers have identified six eco-design strategies that can be selected depending on the business model of the company [14]:

1. Design for attachment and trust: design that encourages consumers to have a deep connection with the product and the connection help consumers to extend product lifespan. As they are less likely to throw products that have strong and emotional attachment.
2. Design for durability: adding product reliability and decreasing failure feasibility. Designer task is to match the economic and stylistic lifetime of the product. For instance, it is not making any sense for temporary disposable product to have high durability.
3. Design for standardisation and combability: designing parts of product that can be interchangeable with readily available parts to facilitate repair and extend product life usage. This to create reuse habit and reduce overall consumption as one product can be repaired and multipurposed. For instance, charging phone

and table with the same charging device instead of two different chargers.

4. Design for maintenance and repair aims to prolong product life usage by adding product maintenance. Repair can be laborious, especially in high developed countries with higher labour taxes. Sometimes, repairs can be more expensive than just buying a new one.
5. Design for adaptability and upgradability that will allow for product to be modified in the future. Product features may change over time; therefore, they need to be updated. For instance, a child's highchair that can be transformed into a dining room chair as the child ages grow. A computer software updates can make it easier for products to adapt technological change, but sometimes the speed of technological development exceeds the speed of the upgrade.
6. Design for ease of disassembly and reassembly. They usually come along with design for ease of maintenance and repair. Products are designed in parts so they can be removed and reassembled. This actions not only increase repairability and reusability of products but increase the recyclability of products.
7. Design for recycling. It focuses on applying specific design techniques to improve the recovery of materials in the recycling process. The technique involves avoiding the use of mixed materials so that the product can be recycled more easily.
8. Design for dematerialization. The strategy can be achieved by reducing packaging and numbers of material type. In some cases, a product may be replaced with a service that use less resources. One example is to move forward to streaming service instead of buying CD, DVD or blue ray disks.

Role of designer in eco-design

Product designers have important role to play in eco-design because of their position at the initial stages of the product development process (PDP), where the design brief is the most important decision to be made. The brief summarizes all the decision that deals with cost, product appearance, material selection, innovation, product functionality, environmental impact, and quality perceptions (endurance, reparability, and durability) [15]. Despite this important role and decision to be made, there has been limited studies how eco-design put into real design project.

The project is about developing a furniture for early childhood student in Lentera Harapan School (LHS) in Rote, NTT. The school project is an integrated community service project for the school of design. The architect's department designed the building, the interior laid out the school space, visual communication designed the sign system inside and outside the building, and finally the furniture designed by the product design department. The aim is to bring equal education and facilities for children living in remote and to apply eco-design strategies in the design process. As Rote is so far away from the researcher 's location, the amount of resources and energy needed to deliver the design solution must be as efficient as possible.

2. METHODS

The design study case is structured following the standford design thinking phase. It consists of five stages of empathize, define, ideation, prototype, and test. This cycle is the fastest way to improve creative outcome [16]. Tim Brown, IDEO 's CEO, one of the key people in design thinking development, defined design thinking as a thinking method that uses the designer's sense and ability to match human needs with technological feasibility and business model and strategy visibility. These combinations transform into market opportunities bringing market value [17]. Design thinking 's core is human-centered design. The study integrates eco-design strategies within the design thinking framework.

Human-centered design is based on empathizing human needs, using tangible visualization and models to solve difficult problems. After defining a problem, the process may go back to empathize stage to make sure the defining problem is what the user's problem and aspiration. Then an idea can jump directly to the test stage or go through prototyping either way they should be refine back to the ideation process. The goal is to get user feedback as early as possible and then continuously refine to find the best design that really solves problems.

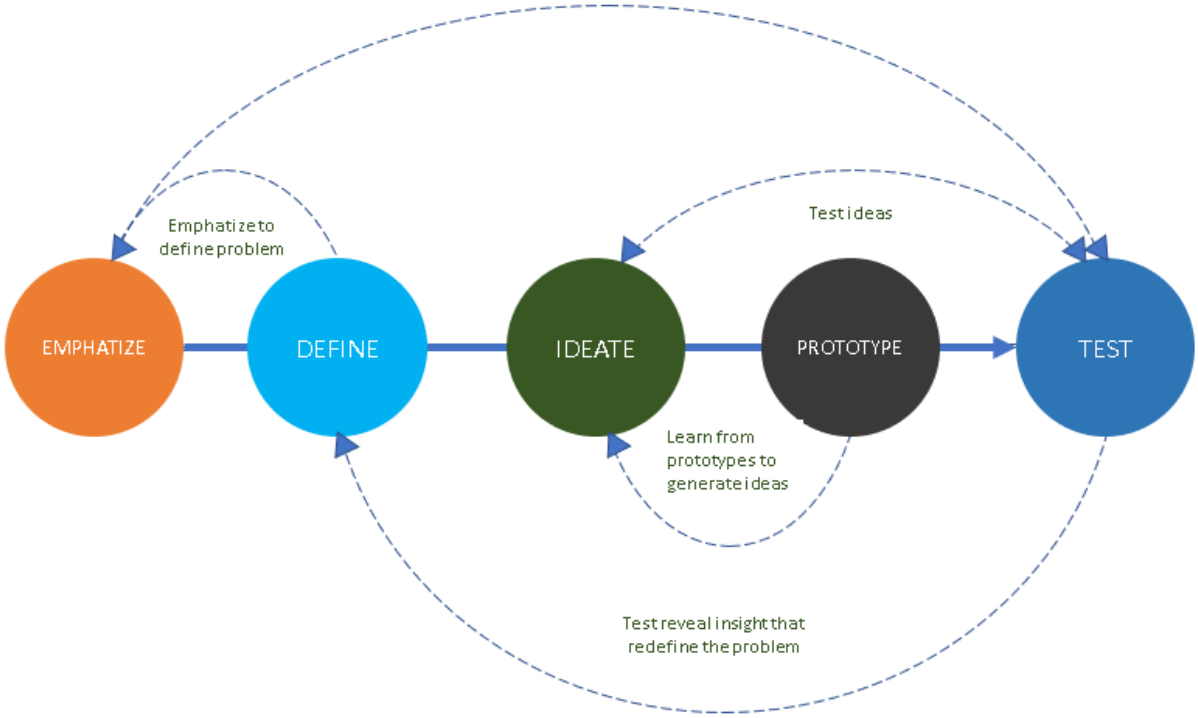

Figure 1 Design Thinking Framework
Source: Developed from Stanford Design Thinking, Plattner (2009)

3. RESULT

The study results are structured following the research framework

Empathize Stage

The empathy was built up through a video call interview with the teacher of LHS as Rote is far from the author's location in Banten and direct observation from the LHS near the author's location, which is Curug LHS. The Curug LHS used the same curriculum as Rote's LHS. From the interview and observation several problem topics were founded:

1. Lack of room

As LHS is a budget school. The current class consists of 5 x 5 m, with a total of 15 students and 1 teacher. Space restrictions may hinder active learning that is key to the curriculum of early childhood education. In addition, Rote has hot weather, as it nears the ocean. Sixteen people in 25 m^2 enclosed space are very crowded and become a crucial problem.

2. Lack of school equipment

Because there is so little space and more students than furniture, five students are stuck in one table. They have little room to study. The existing furniture is made of plastic, a material that is foreign to Rote. So, it can't be fixed when it's broken.

3. Lack of mobility

Since the room is limited and the furniture is already consumed the spaces, students do not have much space for activities that require a lot of movement, such as "Gerak dan lagu."

Figure 2 *SLH Rote Existing Condition*
Source: Researcher's data, 2019

4. Short attention span of the student of early childhood.

Observation and literature studies have shown that children between 3-6 years of age have limited attention span. The curriculum is therefore based on active learning. As a result, out of the total four hours of learning at school, only about one-hour furniture is used per student.

Define stage

From the empathize stage, the main problem faced by the LHS school is defined, which is the existing furniture doesn't provide the possibility to do active learning, which is key for childhood education, and it takes so many spaces in the room. Because the furniture is so fixed and cannot be stacked, this creates a space problem in a very tight space. As a result, the design explores the idea of modularity and knockdown. Thus, furniture can be adapted to different learning contexts and spaces.

After the empathizing stage, designers decide the best eco-design strategies that can be applied within Rote project context is the Design for standardisation and combability, Design for maintenance and repair, and Design for ease of disassembly and reassembly.

Ideation Stage

Moodboard is constructed to give direction to the design process. The design explores the concept of a modular and knock-down system.

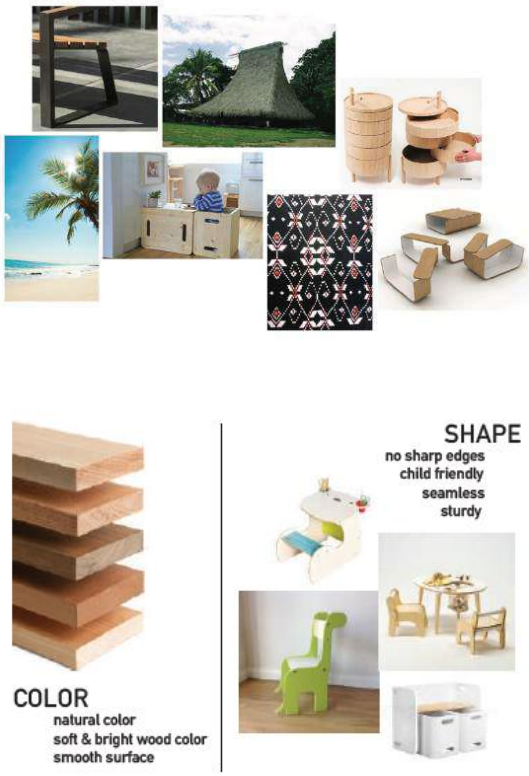

Figure 3 Design Moodboard

Several design ideas have been generated from the moodboard. The shape of the table and the backrest is taken from the Mosalaki roof, an ancient architectural style of the Rote House. So the modular shapes comes from the indigenous culture.

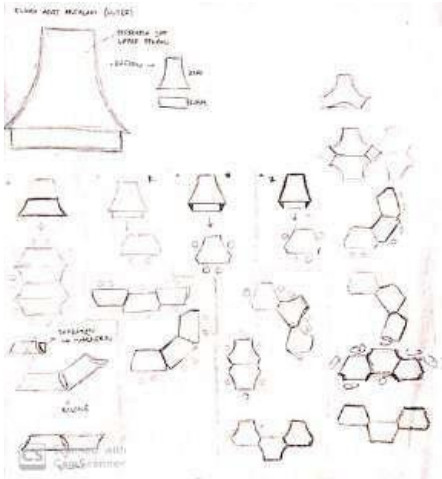

Figure 4 Sketch (Source: researcher's data, 2019)

Design for standardization and combability

Reflecting the eco-design strategies, that each chair and table should be in standard and compatible with each other. The standardization process is done by the seat is the third size of the tabletop. It is founded that material waste from the furniture can be useful and can be used as a means of promoting togetherness in the classroom. So, the MDF waste is used to make an educational puzzle toys for students to learn more about the Rote's cultural icon.

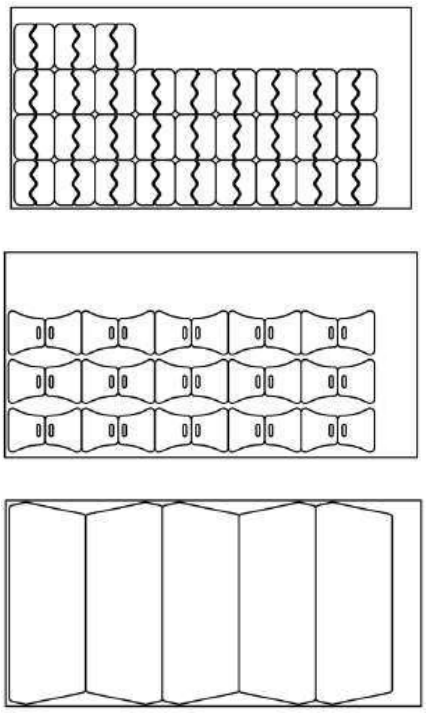

Figure 5 Product Standardization and Compatibility Simulation In 3d Modelling (Source: researcher's data, 2019)

Design for maintenance and repair and Design for ease of disassembly and reassembly

As Rote is far from the designer's location, the products need to be disassembled in a flat pack to ease shipping and reassemble easily in Rote. The instruction gives step by step assembling process.

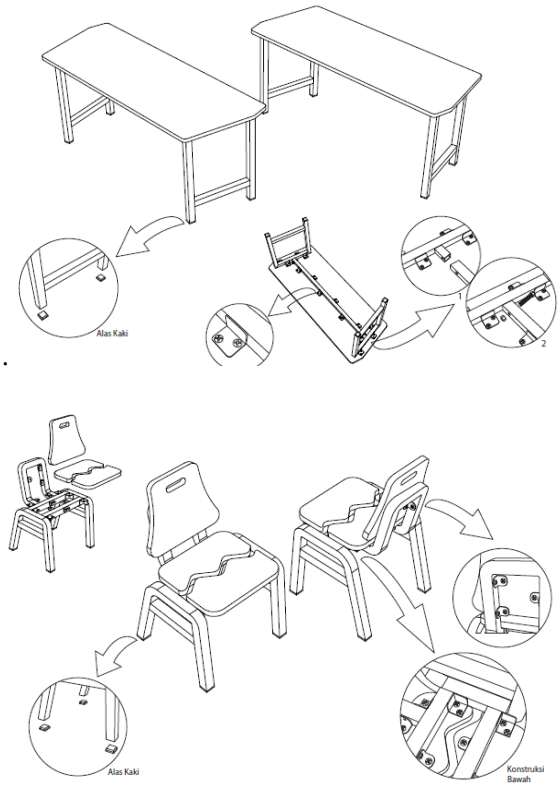

Figure 6 Table knockdown and Chair assembly instruction (Source: researcher's data, 2019)

Figure 7 Furniture in Shipment Packaging (Source: researcher's data, 2019)

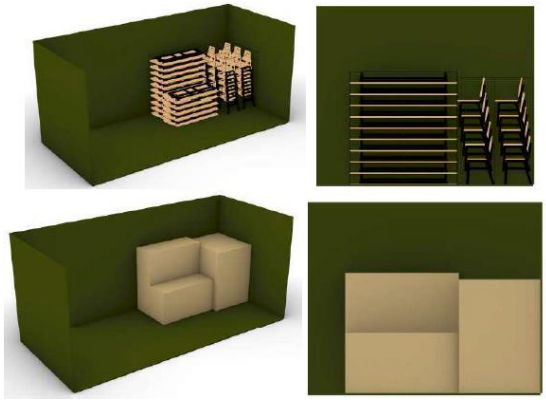

Figure 8 Shipping Simulation in 20 feet container to Rote (Source: researcher's data, 2019)

Prototyping Stages

Due to the covid 19 pandemi situation, the design cannot be prototyped in real material, which is MDF for tabletops and 2 mm metal thickness for legs. So, this is a 3d print. The design is a table that can be knocked down for ease of shipping and a chair that can be stacked up to five. The table was designed for two students. Furniture can be adapted to different learning styles and space limitations, since it can be easily disassembled and stacked. The furniture is designed for a new school built by the architectural design team in which each class has a size of 8 x 8 m, much larger than the previous class of 5x5 m. The furniture is stackable, so it won't create a space problem again.

Figure 9 3d printed prototype (Source: researcher's data, 2019)

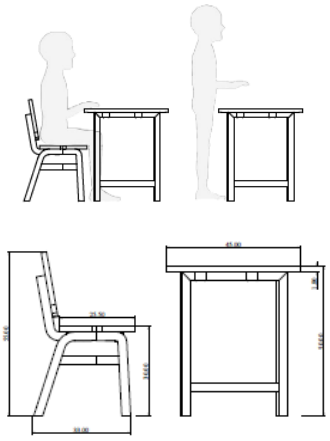

Table length	**120 cm**
Table depth	45 cm
Table height	50 cm
Chair length	34 cm
Chair depth	35 cm
Chair height	55 cm

Figure 10 Product Dimension
Source: researcher's data, 2019

Figure 11 Twenty-Five Puzzle made from MDF Waste

Source: researcher's data, 2019

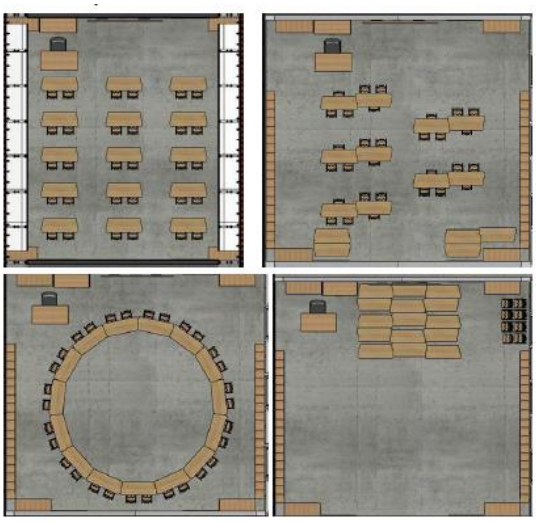

Figure 12 New Furniture Active Learning Simulation (Source: researcher's data, 2019)

Test Stage

As the new modular furniture is not made in real size and real material. We test the design with 3d animation via whatsapp call to four LHS's teachers. The feedbacks are in scale of 1 (bad) – 5(good)

No.	Factors	A	B	C	D	Mean
1	Design	3	4	4	4	3.75
2	Color combination	3	5	5	5	4.5
3	Material combination	4	5	5	3	4.25
4	Size	4	5	4	5	4.5
5	Storing efectiveness	4	4	4	4	4
6	Practical ability	3	4	5	3	3.75
7	Active learning implementation	5	5	5	5	5
8	Comfort	4	5	5	4	4.5
9	Reuse waste	5	5	5	4	4.75
Overall mean						4.3

Open ended feedback

No	Factors	A	B	C	D
1	Does the design	Little, not really	Enough	Yes	There should be two

	represent Rote?	represent Rote			patterns of color like Rote tenun
2	Favorite features	The backrest looks like Rote weaving	Reuse waste	All of it	Modular configuration
3	Lackness	Color combination is to dull	None	None	The metal part seems so heavy for the student to operate
4	Inputs	The backrest can be higher so it represents Mosalaki's roof more and maybe add storage	None	None	The metal part seems heavy
					with sasando's carving

From this feedback, another color tone is proposed.

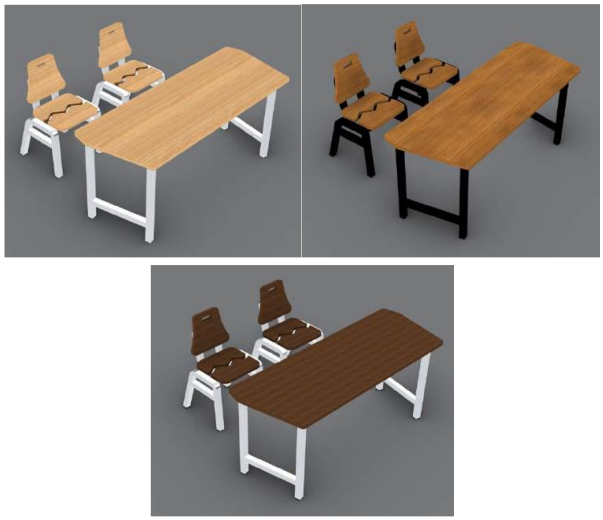

Figure 13 Product Color Alternatives (Source: researcher's data, 2019)

4. CONCLUSION

The study concludes the framework on how to integrate eco-design strategies within design thinking framework.

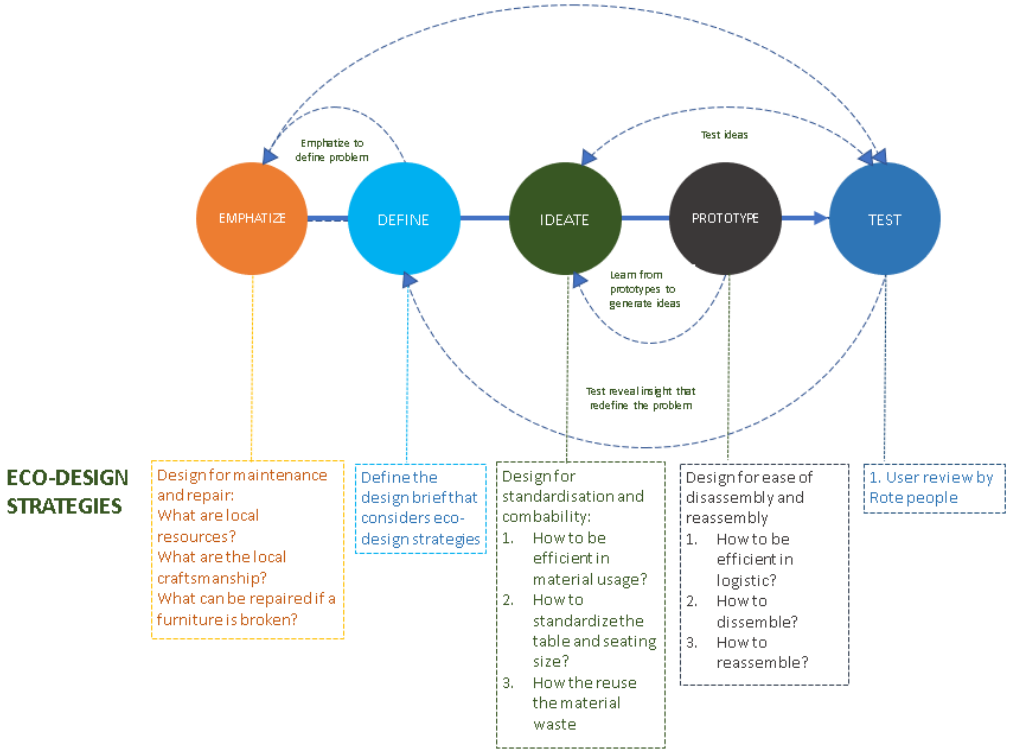

Figure 14 Study Result Framework Source: researcher's data, 2019

Some of the design process recommendations that can be drawn from the study how design thinking framework integrating eco-design strategies in the process are as follows:

1. At the empathize stage, ensure that the study connects with all stakeholders through interviews and observation. In the project, we are working with teachers, funders, other departments, and contractors involved in the projects. The question needs to be asked during the empathize stage is about the local resources and capability to ensure that the product is repairable in the Rote.

2. At the define stage, there should be a strong cause and effect analysis to really define the root cause of the problem. It is very important to ensure that the design solves the crucial and urgent problem, not the latter. Aside from identifying the core problem, in this stage designer should decide which eco-design strategies that suit and achievable within the project context.

3. At the stage of ideation, the mindset here is quality over quantity. In this stage the eco-design strategies are implemented. First, to reduce amount of energy and resources waste during prototyping process the 3d modeling must be made as detailed as possible so that all the construction can be evaluated as soon as possible. Through detail 3d modelling error in production can be prevented. All the dissemble and reassemble for shipment and material usage are simulated in 3d modeling. Once there is a solid idea, test the prototype to get feedback and go back to the process of ideation to refine the first idea. Innovation comes from the continuous process of improving ideas.

4. At the prototype stage, use digital prototyping as it can bring ideas to life quickly and efficiently. Through digital manufacturing, the proportion and construction can be tested. The design for maintenance and repair can also be simulated and visualized to the stakeholders through 3d printing. The project used particle board and metal, taking consideration that both materials can be repaired easily at local wood workshop in Rote.

5. It is very important to deliver ideas through storytelling at the test stage. So, the user knows the process and the activities that happen to be related to the object. For example, the logistics, the disassembly, the modular arrangement must be clearly explained through a scenario before the user gives any feedback on the design.

ACKNOWLEDGMENTS

We thank our Faculty of Design Dean Dr. Martin L. Katoppo S.T.M.T., and the Chairman of Center for Research and Community Development (CRD) Dr.-Ing.Ihan Martoyo, S.T., M.Sc. This article is a research publication registered in Center for Research and Community Development (CRD) of Pelita Harapan University under number PM 082/SOD-UPH/I/2020.

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