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Six Sigma Meets Agile: Innovations in Batik Ecoprint Development in Indonesia

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Abstract

This study aims to evaluate the effectiveness of the Six Sigma method in improving the quality control process of ecoprint batik production among Indonesian micro, small, and medium enterprises (MSMEs), which often face issues related to inconsistent product quality due to the lack of standardized procedures. The research adopts the Six Sigma approach through the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, supported by both primary data from direct observation and secondary data from production records and defect logs. An agile framework is also integrated to design a prototype classification system for identifying leaf types and matching them with appropriate production methods. The implementation of the Six Sigma methodology led to significant improvements in specific production stages. The sigma level in the pattern formation process improved by 39.78%, and fixation quality increased by 41.38%. However, improvement in the scouring and mordanting process was limited to 6.9%, primarily due to the absence of standardized operating procedures regarding raw material usage. The integration of Six Sigma and agile principles successfully enhanced the quality of ecoprint batik production, particularly in critical stages of the process. The findings underscore the need for clear and consistent standards to support broader quality improvement. This research provides a structured framework that can be adopted by MSMEs to establish quality management standards, reduce production defects, and enhance the market competitiveness of ecoprint batik as a sustainable Indonesian cultural product on a global scale.

Keywords: Agile, Batik Ecoprint, Indonesia, Six sigma.

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1. Introduction

Batik is an Indonesian cultural heritage that symbolizes the beauty and richness of traditional art. Established by UNESCO on September 9, 2008, batik is an Intangible Cultural Heritage (ICH) owned by the Indonesian nation. In Indonesia, the batik industry is largely driven by Micro, Small, and Medium Enterprises (MSMEs) actors who are able to produce batik with sales on both a national and international scale. Along with the passage of time and the rise of programs to carry the theme of ecopreneurship, the batik industry has experienced innovation in terms of the raw materials used and the manufacturing process, namely ecoprint batik. Ecoprint batik is a type of batik that, in the manufacturing process, uses environmentally friendly principles by using natural materials such as leaves, fruits, and spices to print patterns on the fabric.

This is the advantage and uniqueness of ecoprint batik when compared to conventional methods that use wax on cloth with various dyes that use chemicals that have the potential to damage the environment [1]. In 2023, Indonesia is a very high-ranking country as the largest batik-producing nation in the realm of exports. The countries that are the largest batik export destinations for Indonesia include the United States (US $10,033,368) as the first country with the highest level of Indonesian batik export volume, followed by Germany (US $507,214) and Singapore (US $284,693) [2]. So it can be concluded that Indonesia is a country with a large producer of ecoprint batik, but this is still inversely proportional to the quality produced [3].

Figure 1.
Examples of Good Quality (Left) and Poor Quality (Right) Ecoprint Batik.

Some of the results of ecoprint batik that carry the concept of environmentally friendly show shortcomings in terms of product quality. Quality in ecoprint batik can be defined as the level of excellence and attractiveness of products that include aspects of aesthetics, durability, and added value, so the quality in ecoprint batik is expected to increase selling value and public buying interest.

MSMEs in Indonesia, as actors in the eco-print batik industry, do not yet have a quality standard for the production of eco-print batik. This has an impact on the minimal level of sales of eco-print batik in Indonesia compared to conventional batik, and poor quality is considered to be one of the most influential factors.

This research aims to address problems that arise related to the quality of ecoprint batik. The chosen problem-solving approach emphasizes the improvement of the quality of ecoprint batik, with the aim that the ecoprint batik MSME industry can implement quality management in each of their ecoprint batik production lines. With the implementation of a quality standard, it is expected that ecoprint batik can meet consumer expectations regarding the quality demands of environmentally friendly ecoprint batik. The search for a standard in quality is determined according to the *root cause* search process with the application of the Six Sigma method.

The Six Sigma method, which is based on quality control management, is identical to its sequential nature, namely the Six Sigma cycle requires sequential work and calculations that are quite time-consuming in it Achibat et al. [4]. This will be combined with the Agile method, wherein the Agile method every process in Six Sigma will be done several things simultaneously in accordance with the agile principle that prioritizes speed [5]. Some indicators for Six Sigma will be adjusted in accordance with the adoption of agile so that it can carry out several quality controls simultaneously in a relatively fast time [6]. With the integration of Six Sigma and Agile Method, it is expected to produce significant benefits, especially in terms of quality control in the ecoprint batik industry in a relatively short time.

2. Research Methods

This research uses the Six Sigma method, which is a strategic approach to reducing variation in the production process, with the aim of reducing costs while increasing customer satisfaction. One of the main advantages of the Six Sigma method is its ability to identify and eliminate the root causes of problems that hinder quality, and demonstrate significant improvements [7]. The Six Sigma approach is applied to find the root cause of quality problems in ecoprint batik production. This research takes several ecoprint batik industries in Indonesia as the object of study to identify the causes of defects and achieve a very low error rate [8].

The research data were collected through two types of sources, namely primary data obtained through direct observation and field experiments. The information collected includes the production process, the types of defects that often occur, and the main causes of these defects. Meanwhile, secondary data include information on the amount of production and types of defects reported by the ecoprint batik industry. After the data are collected and classified, data processing is carried out using the DMAIC (Define, Measure, Analyze, Improve, Control) method, which consists of five steps, namely [9].

- Define is the first step to determine which processes will be evaluated
- Measure is a step that aims to measure the ability of the production process to produce products that meet product quality criteria.
- Analyze is the stage of analyzing by using cause and effect diagrams or fishbone diagrams to identify the source of quality problems. This tool helps determine the root cause of the problem so that the right solution can be found.
- Improve is a step in taking recommended corrective actions to solve the problems that have been identified
- Control is the stage of control to ensure that after improvements are made, the process remains in control and new problems can be addressed immediately. Evaluation is carried out to ensure the success of improvements and prevent the same problems from recurring.

Thus, by applying the DMAIC method thoroughly, this study aims to demonstrate how the Six Sigma approach can support quality control in the ecoprint batik industry, thereby making a significant contribution to improving product quality and competitiveness.

3. Results and Discussion

The Six Sigma method in this study uses the Define, Measure, Analyze, Improve, and Control (DMAIC) method which is carried out sequentially [10]. The results obtained are as follows:

3.1. Define

The Define process aims to explain the problems and objectives of this project. The approach in the Define Process is done by creating a:

3.1.1. SIPOC (Supplier, Input, Process, Output, Customer) Diagram

The SIPOC diagram is a tool used in this research to identify the flow of raw materials, processes, and outputs of the ecoprint manufacturing process. The SIPOC diagram represents the process as a whole, so that it can help researchers to find potentials for improving non-conformities as a whole [11].

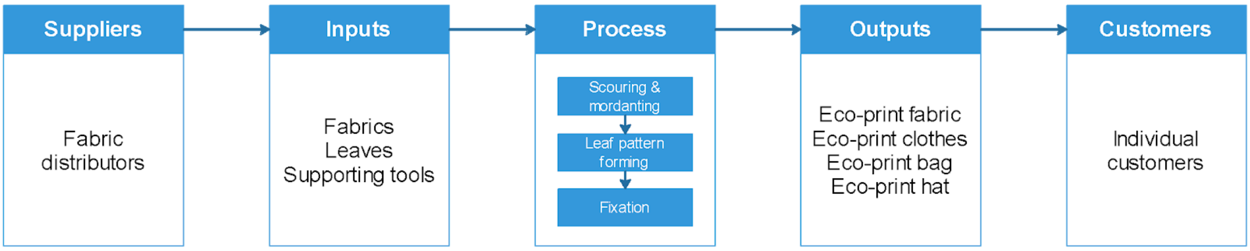

Figure 2.
SIPOC Diagram Results.

3.1.2. CTQ Characteristics

Critical To Quality (CTQ), namely the requirements of QC to achieve customer satisfaction, so that there are no complaints from the previous process [12]. In the ecoprint batik production process, there are mainly 4 main processes, namely scouring, mordanting, leaf pattern formation, and fixation.

Table 1.
CTQ characteristics.

Process	Customer Needs
Scouring (cleaning fibers and removing deposits on the fabric) & Mordanting (removing components that inhibit the absorption of color on the fabric and as an intermediary medium for binding color to ecoprint materials)	There are no tears in the fabric
	No dirt/spots on the fabric
Leaf pattern formation	The result of transferring the leaf color to the fabric is clear and similar to the original color.
	The eco-print pattern is clearly visible when boiling is complete
Fixation	Bright color and no fading
	The final coloring result is similar to the original or target (not older or younger)

3.1.3. Check Sheet

Check sheets aim to collect, record, and analyze data systematically [13]. In this study, the check sheet was used to identify the number of nonconformities obtained in each eco-printing process. Each eco-printing process contributes to the appearance of nonconformities in the final product. In real terms, each nonconformity found will affect the quality and economic value of the final product.

Table 2.
Check sheet of scouring and mordanting process

Scouring & Mordanting Process			
Period (1 Day)	**Number of Products Inspected (Population)**	**Number of Nonconformities**	**Nonconformity (%)**
1	3	1	33.33%
2	4	1	25.00%
3	3	1	33.33%
4	5	2	40.00%
5	3	1	33.33%
6	3	1	33.33%
7	3	1	33.33%
8	4	1	25.00%
9	5	2	40.00%
10	5	1	20.00%
11	5	1	20.00%
12	3	2	66.67%
13	4	1	25.00%
14	3	2	66.67%
15	5	1	20.00%
16	4	1	25.00%
17	3	1	33.33%
18	3	1	33.33%
19	4	1	25.00%
20	5	2	40.00%
Total	77	25	32.47%

Table 3.
Check sheet of leaf pattern formation process.

Leaf pattern formation			
Period (1 Day)	**Number of Products Inspected (Population)**	**Number of Nonconformities**	**Nonconformity (%)**
1	3	1	33.33%
2	4	1	25.00%
3	3	1	33.33%
4	5	2	40.00%
5	3	2	66.67%
6	3	3	100.00%
7	3	2	66.67%
8	4	2	50.00%
9	5	3	60.00%
10	5	1	20.00%
11	5	2	40.00%
12	3	1	33.33%
13	4	2	50.00%
14	3	1	33.33%
15	5	2	40.00%
16	4	1	25.00%
17	3	2	66.67%
18	3	2	66.67%
19	4	2	50.00%
20	5	2	40.00%
Total	77	35	45.45%

Table 4.
Check sheet of fixation process

Fixation			
Period (1 Day)	**Number of Products Inspected (Population)**	**Number of Nonconformities**	**Nonconformity (%)**
1	3	2	66.67%
2	4	2	50.00%
3	3	1	33.33%
4	5	2	40.00%
5	3	1	33.33%
6	3	1	33.33%
7	3	1	33.33%
8	4	2	50.00%
9	5	2	40.00%
10	5	2	40.00%
11	5	1	20.00%
12	3	1	33.33%
13	4	2	50.00%
14	3	2	66.67%
15	5	1	20.00%
16	4	1	25.00%
17	3	2	66.67%
18	3	1	33.33%
19	4	2	50.00%
20	5	1	20.00%
Total	77	30	38.96%

Based on observations, it was found that the level of nonconformity of each process was still quite high, with a range of 32% - 45%, while the nonconformity target allowed by management was 5% of total production. This number is considered very high, which affects the reputation and potential profits earned by the company. Therefore, the general goal/objectives of this Six Sigma project are to reduce the number of nonconformities to 5% or equivalent to 4 units/month.

3.2. Measure

The Measure stage is carried out to check the status or condition of the problem that has been obtained [14].

3.2.1. Determination of Nonconformity Criteria

The quality characteristics that have been defined through CTQ in the previous define stage are then translated into the types of nonconformities that are the focus of Six Sigma project improvement. Each process can produce nonconformities caused by errors in processes, procedures, materials, and so on that occur in the process. Furthermore, improvement efforts will be focused on the selected nonconformities.

Table 5.
Determination of Nonconformity Criteria.

Process	**Customer Needs**	**Nonconformance Criteria**
Scouring & Mordanting	There are no tears in the fabric	Ripped fabric
	No dirt/spots on the fabric	Dirty cloth
Leaf pattern formation	The result of transferring the leaf color to the fabric is clear and similar to the original color.	Color conformity of the pattern during the transfer process
	The eco-print pattern is clearly visible when boiling is complete	Pattern clarity
Fixation	Bright color and no fading	Color clarity of the final product
	The final coloring result is similar to the original or target (Not older or younger)	Color suitability of the final product

3.2.2. Performance Baseline Measurement with Sigma Value

The next stage in measurement is the measurement of the sigma value for the existing condition of the eco-print production process, which will be used as a baseline in improving the quality of the final product. Measurement of baseline performance will be carried out for each customer's needs and nonconformity criteria using the calculation of the sigma value. The sigma value itself shows a measure of how good a process is, especially in the context of uniformity and quality. The sigma value indicates the level of variation or defects in a process compared to the desired specification or standard. The sigma value is further indicated by a value of 1-6, where the higher the sigma value, the lower the Defect per Million

Opportunities (DPMO) value, which means the process quality is getting better. In general, the sigma value can be represented by the DPMO value, which refers to the following formula.
DPMO=Number of defects Number of units produced x Number of opportunities for defects (CTQ) x 1,000,
The reference and interpretation of the sigma value can be seen in Table 6.

Table 6.
Sigma Performance.

Sigma Value	DPMO	COPQ (Cost of Poor Quality)	Description
1-Sigma	691.42	Not calculable	Highly inefficient process, highly uncompetitive
2-Sigma	308.538	Not calculable	Better process but still not optimal, average Indonesian industry
3-Sigma	66.807	25-40% of sales	Good enough process
4-Sigma	6.210	15-25% of sales	Processes are close to good quality, USA industry average
5-Sigma	233	5-15% of sales	Highly efficient process
6-Sigma	3.4	< 1% of sales	Nearly perfect process, World-class industry

Note: every 1-sigma increase/shift will give an increase in profit of about 31% of sales.

3.2.3. Scouring & Mordanting Process

In the scouring & mordanting process, there are two CTQs that are the focus of research and improvement, namely torn fabric and dirty fabric. Based on this information, the DPMO value and average sigma value will reflect the process capability of the scouring and mordanting process, which can be seen in the following Table 7.

Table 7.
CTQ of Scouring and Mordanting Processes.

Perio	Number of Products Inspected (Population)	Number of Nonconformities	Number of Potential CTQs	DPMO	Sigma
1	3	1	2	166666.6667	2.467
2	4	1	2	125000	2.650
3	3	1	2	166666.6667	2.467
4	5	2	2	200000	2.342
5	3	1	2	166666.6667	2.467
6	3	1	2	166666.6667	2.467
7	3	1	2	166666.6667	2.467
8	4	1	2	125000	2.650
9	5	2	2	200000	2.342
10	5	1	2	100000	2.782
11	5	1	2	100000	2.782
12	3	2	2	333333.3333	1.931
13	4	1	2	125000	2.650
14	3	2	2	333333.3333	1.931
15	5	1	2	100000	2.782
16	4	1	2	125000	2.650
17	3	1	2	166666.6667	2.467
18	3	1	2	166666.6667	2.467
19	4	1	2	125000	2.650
20	5	2	2	200000	2.342
Total	77	25	2	167916.6667	2.462

3.2.4. Leaf Pattern Formation Process

Table 8.
CTQ of Leaf Pattern Formation Process.

Perio	Number of Products Inspected (Population)	Number of Nonconformities	Number of Potential CTQs	DPMO	Sigma
1	3	1	2	166666.6667	2.467
2	4	1	2	125000	2.650
3	3	1	2	166666.6667	2.467
4	5	2	2	200000	2.342
5	3	2	2	333333.3333	1.931
6	3	3	2	500000	1.500
7	3	2	2	333333.3333	1.931
8	4	2	2	250000	2.174
9	5	3	2	300000	2.024
10	5	1	2	100000	2.782
11	5	2	2	200000	2.342
12	3	1	2	166666.6667	2.467
13	4	2	2	250000	2.174
14	3	1	2	166666.6667	2.467
15	5	2	2	200000	2.342
16	4	1	2	125000	2.650
17	3	2	2	333333.3333	1.931
18	3	2	2	333333.3333	1.931
19	4	2	2	250000	2.174
20	5	2	2	200000	2.342
Total	77	35	2	235000	2.222

3.2.5. Fixation Process

Table 9.
CTQ of Fixation Process.

Perio	Number of Products Inspected (Population)	Number of Nonconformities	Number of Potential CTQs	DPMO	Sigma
1	3	2	2	666666.6667	1.069
2	4	2	2	250000	2.174
3	3	1	2	166666.6667	2.467
4	5	2	2	200000	2.342
5	3	1	2	166666.6667	2.467
6	3	1	2	166666.6667	2.467
7	3	1	2	166666.6667	2.467
8	4	2	2	250000	2.174
9	5	2	2	200000	2.342
10	5	2	2	200000	2.342
11	5	1	2	100000	2.782
12	3	1	2	166666.6667	2.467
13	4	2	2	250000	2.174
14	3	2	2	333333.3333	1.931
15	5	1	2	100000	2.782
16	4	1	2	125000	2.650
17	3	2	2	333333.3333	1.931
18	3	1	2	166666.6667	2.467
19	4	2	2	250000	2.174
20	5	1	2	100000	2.782
Total	77	30	2	217916.6667	2.279

In general, the sigma value obtained from the identification of each process is at the 2-sigma level, which indicates a process that is not optimal, with the possibility of defects out of one million products being 308,500 or 30.85%. This shows that this result is still very far from the company's target. In addition, in the types of industries that belong to the manufacturing sector or industries with low-risk levels, the targeted sigma value is 3 - 5. Therefore, this condition is further analyzed to find the root cause of the problem as a basis for implementing improvements.

3.3. Analyze

The Analyze process is carried out by analyzing the current situation and finding solutions to achieve goals.

The analyze stage aims to identify and analyze existing situations and conditions to find potential solutions in achieving goals [14]. As explained in the define stage, the goals to be achieved in this Six Sigma project are to reduce the level of nonconformity of the final product to improve the quality and economic value of the eco-print products produced. At this stage, the dominant causes of potential nonconformities of each eco-printing process were identified using cause-and-effect diagrams and interrelationship diagrams to find important factors that have a major impact on the system.

Basically, cause-and-effect diagrams (also known as Fishbone Diagrams) and interrelationship diagrams are based on the results of brainstorming with related parties or stakeholders to find the root of the problem together. Therefore, at this stage, the person in charge of production plays an important role in identifying the variables or elements involved in the eco-printing system.

3.3.1. Fishbone Diagram

A fishbone diagram is an analytical tool included in the Seven Tools that aims to identify, organize, and analyze the causes of problems [15]. Furthermore, the causes of a problem are visualized in a fishbone diagram, with the main problem at the head end and the causes in the branching "bones". The identified causes of problems are classified into six general categories referred to as the 6Ms, which consist of man, machine, material, method, measurement, and mother nature (environment).

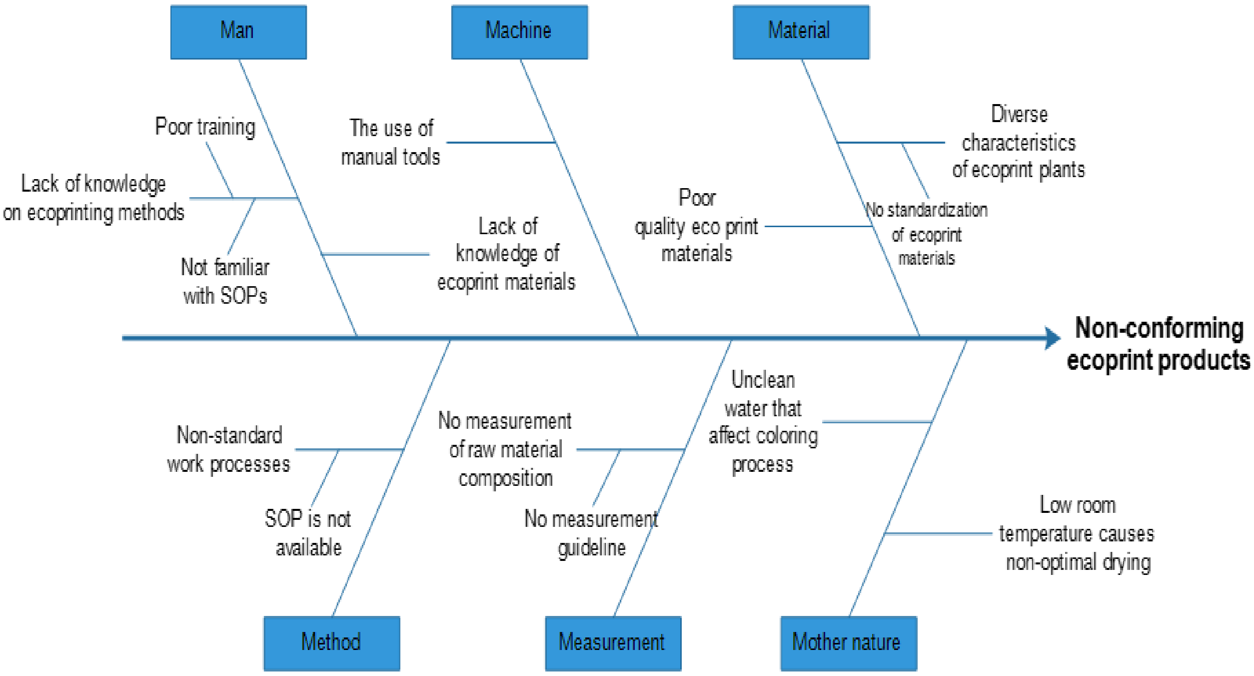

Figure 3.
Fishbone diagram.

The results of the analysis of the fishbone diagram show that there are nine potential causes that lead to the occurrence of defects or nonconformity of ecoprint products that come from six categories. Some of the identified causes can then be broken down again to find the root cause of the problem. The next step is to focus the search for root causes to facilitate the decision-making process, especially the determination of the main solution to be applied to this Six Sigma project. The tool used is the interrelationship diagram to find one major cause of the high defective products of ecoprint products.

3.3.2. Interrelationship Diagram

Interrelationship diagrams aim to determine the key drivers and outcomes of suboptimal ecoprint results. The first step of preparing an interrelationship diagram is to determine the important elements of the problem [16]. In this study, the elements used came from the identification of the causes of the problem obtained from the Fishbone Diagram, where the Fishbone Diagram did not accommodate the priority level of problem-solving. In addition, it can be seen from some of the identified causes that some problems are caused by similar and interrelated root causes. Therefore, the interrelationship diagram is used by researchers to understand the relationship between complex elements, and the complexity is visualized in a simpler way. The problem elements of the Fishbone Diagram are described as follows.

1. Non-conforming eco print products
2. Diverse characteristics of eco print plants

3. Poor quality eco print material
4. The use of manual tools
5. Lack of knowledge of eco print materials
6. Lack of knowledge on eco printing methods
7. Non-standard work process
8. No measurement of raw materials composition
9. Unclean water
10. Low room temperature
11. SOP or guideline or standardization is not available

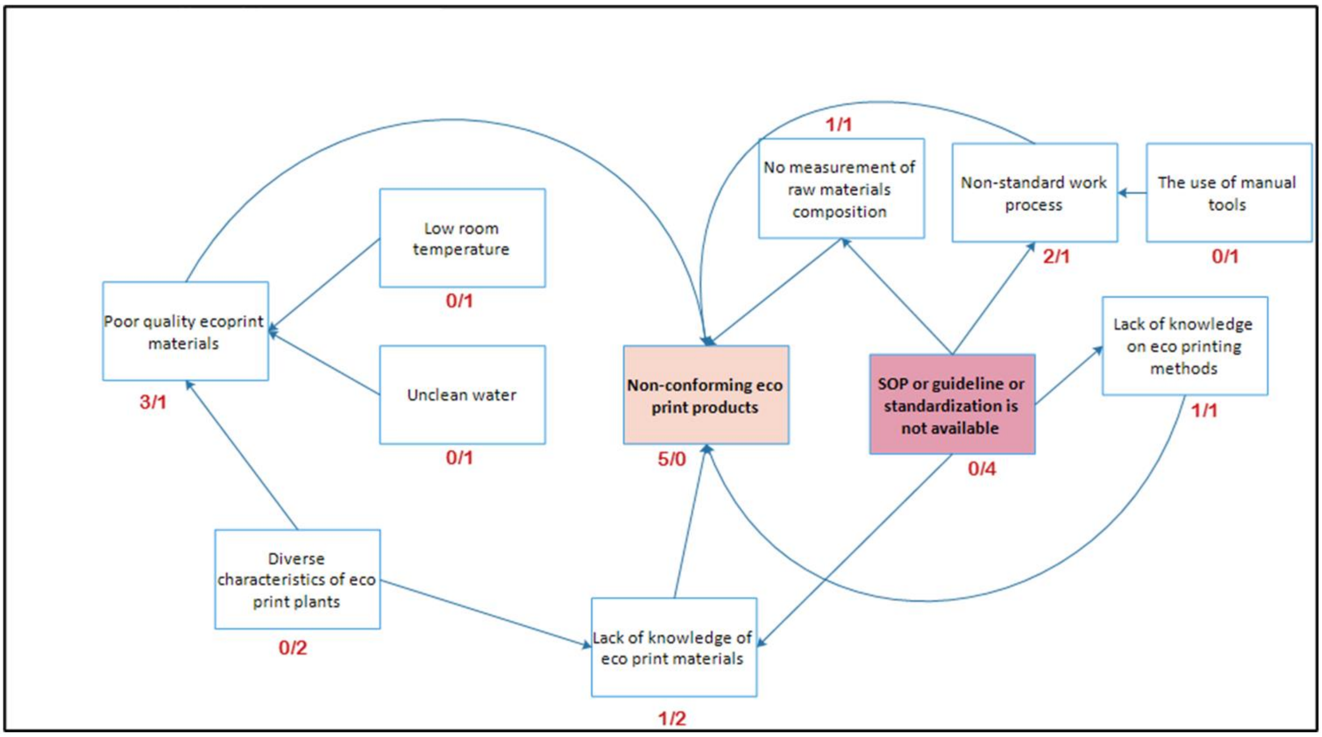

Figure 4.
Interrelationship Diagram Results.
Note: In/Out In: The element is affected by other elements (Impact).
Out: The element affects other elements (Causes).

Interrelationship diagrams basically show the causal relationships of various elements to identify the main causes and impacts of the problem. The outgoing arrow indicates that the element affects other elements, which means that the element is the cause of the other elements that are impacted, and vice versa. The results of the identification and analysis of the interrelationship diagram show that the current condition of eco-print production is the high non-conformity of the products produced (seen from the highest in the arrow). Furthermore, the main cause or key driver of this problem is the absence of SOPs or standards set by the company or organization in the ongoing eco-print process. This is indicated by the highest out arrow value of all identified elements. Therefore, the improvement will be focused on creating SOPs and eco-print guidelines that can then be used as the main reference in the production process in the future.

3.4. Improve

The Improve stage aims to implement the solution to achieve the goal [8]. The main goal of this Six Sigma project is to reduce the number of defective products and increase the sigma value of the production process. The implemented solution will focus on solving the root of the problem that has been found in the previous analysis stage, which is the unavailability of Standard Operating Procedures (SOP) or standard guidelines in the eco-print production process, which starts from the selection of raw materials to the finishing process. As defined in the initial stage, eco-print products pass through three main stages, where each production process has the opportunity to cause product defects. Therefore, the main focus of the improve stage of this Six Sigma project is the preparation of SOPs and guidelines that contain the main standards of the production process in order to meet the CTQ that has been determined.

The draft solution in the form of SOPs will be implemented in the form of an agile-based information system. SOP design in the form of an information system is considered more efficient, has higher accuracy, is easily accessible, reduces the risk of human error, facilitates the monitoring and evaluation process, and provides opportunities for integration with other documents. Meanwhile, the agile method is used as the basis for system design because it offers flexibility and efficiency in the design process.

3.5. Eco Print Information System Design

The information system design process starts with determining the needs of the eco-print industry, which will then be implemented into the information system. Based on the analysis of the previous stage, one of the elements that is impacted by the absence of SOP is the lack of knowledge regarding eco-print raw materials, especially the types of leaves. The choice of leaf type is one of the essential aspects of eco-print because it affects the patterns formed, both in terms of shape and color. Essentially, the quality of leaves is defined by two main indicators: leaves that can transfer colors and those that can transfer shape patterns well and perfectly. Therefore, the first step in the information system development is to conduct a leaf type trial to determine the quality of the leaves, which can then be divided into several quality grades: A, B, and C. Grade A is the highest grade that can produce patterns with the greatest similarity to the original form. Grade B is the middle level, and Grade C is the lowest level. This grade difference further affects the quality and selling price. The following table details the classification of leaf quality.

Table 10.
Grade Classification.

No.	Grade	Indicator	Leaf / Flower Type
1	A	The leaf is able to transfer color according to the target color with a tolerance level of 10% and has 80-100% pattern/shape similarity.	Star fruit leaf, Papaya leaf, Paper flower, Gutter flower, Lemongrass leaf, Banyan leaf, Cassava leaf, Moringa leaf
2	B	The leaf is able to transfer color according to the target color with a tolerance level of 11-50% and has 50-79% pattern/shape similarity.	Guava Leaf, Mango Leaf, Betel Leaf, Soka Flower, Teak Leaf, Spinach Leaf
3	C	The leaf is able to transfer color according to the target color with a tolerance level of >50% and a shape pattern similarity level of <50%.	Croton Plant, Allamanda Flower, Ruellia Flower, Frangipani Leaf, Red-stem Purslane Flower, Hibiscus Flower, Jasmine Flower, Ylang-ylang Flower, Rose Flower, Cherry Leaf

Based on the trials, ecoprint material (leaves/flowers) with grade A is capable of producing excellent batik quality when compared to grades B and C.

Figure 5.
Example of Frangipani leaf grade C results.

Figure 6.
Example of Teak leaf grade B results.

Figure 7.
An example of the results of grade A Belimbing leaves.

3.6. Working Instruction

The working instruction is made in accordance with the results of trials to equalize standards in order to achieve high quality in the production of ecoprint batik. The creation of working instructions is based on various techniques and methods in the production of ecoprint, combined with the characteristics of each leaf, which is the root cause of the quality itself.

Table 11.
Framework.

No.	Process	Instructions
1	Mordanting	1. Prepare 4 buckets 2. Put 4 scoops of alum in each bucket 3. Add 2 tablespoons of soda ash to each bucket. 4. Put 5 scoops of water in each bucket 5. After mixing all the ingredients as above, then put the cloth in each bucket that has been filled with alum and soda ash. 6. Soak overnight 7. Squeeze the soaked cloth 8. Let the fabric dry
2	Pounding	1. Prepare 2 pots of water (about 3 liters) 2. Put 5 tablespoons of vinegar in a bucket 3. Soak whole leaves and flowers for 1 hour 4. After one hour drain to reduce water content 5. Prepare plastic and fabric that has been mordanting 6. Then arrange the leaves and flowers on the fabric according to your creativity. 7. Cover the cloth with plastic 8. Pound the leaves and flowers one by one until they reveal their shape and color. 9. Ensure that all leaves and flowers are well crushed to produce the desired shape and color. 10. After that, open the plastic and clean the remaining leaves that stick to the cloth.
3	Fixation	1. Prepare a bucket and 2 scoops of water (equivalent to -+ 3 liters) 2. Prepare 3 tablespoons of salt and alum 3. Combine all the salt, water, and alum in a bucket. 4. Soak the pounded fabric for 10 minutes 5. After 10 minutes of soaking, do another cleaning so that the remaining leaves and flowers that stick to the fabric are gone. 6. Dry in the sun

3.7. Prototype System

In accordance with the implementation of agile methods for the production process of ecoprint batik, a prototype is made. With an In Process Control Checklist system that can be used, it is expected to increase the acceleration of the final result to match the expected [17]. The system was developed by adopting working instructions and sampling techniques to test product quality supported by a database of results from flowers or leaves that match the characteristics of each ecoprint result.

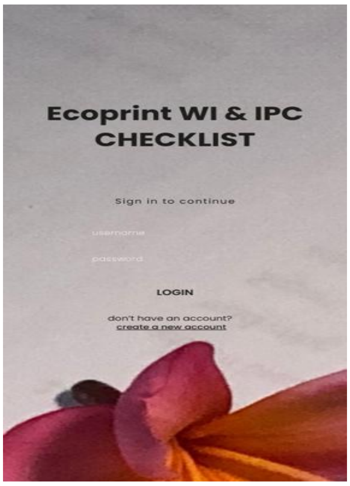

Figure 8.
Initial view of the ecoprint system.

Figure 9.
Leaf Scanning Process through the app.

Figure 10.
Display of cassava leaf scanning results.

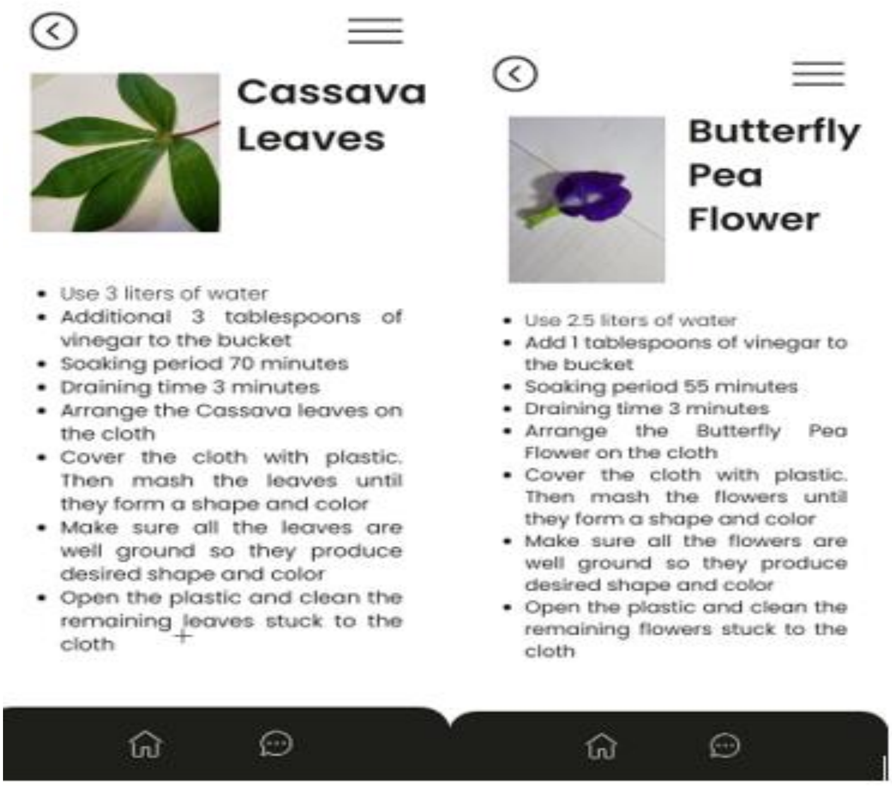

Figure 11.
Scanned leaf-specific descriptions (scenario: cassava leaves) - left, and scanned descriptions (Scenario: butterfly pea flower).

Figure 12.
Expected result of leaf selection.

With the implementation of the system, the agile nature can be adopted in the ecoprint business process. With a high degree of customization according to the characteristics of the leaves (based on the root cause), the producer can quickly determine the production process until the expected results are achieved.

Table 12.
Prototype Adoption Results.

Process	Rate of defective products/month			DPMO Performance			Sigma Value		
	Baseline	After Implementation	% Change	Baseline	After Implementation	% Change	Baseline	After Implementation	% Change
Scouring & Mordanting	25	17	-32.00%	167916.6667	128750	-23.33%	2.462	2.632	6.90%
Pattern formation	35	9	-74.29%	235000	54166.66667	-76.95%	2.222	3.106	39.78%
Fixation	30	6	-80.00%	217916.6667	42500	-80.50%	2.279	3.222	41.38%

3.8. Control

The control stage consists of activities to ensure that the solution in the improve stage has been implemented and has a significant impact or not. The main solution implemented at the improve stage was the creation of an information system containing production SOPs. After the implementation of the prototype system, the control stage is implemented with the aim of measuring whether there is a permanent improvement in terms of quality and the expected end result. Testing of the improvement in the quality of ecoprint batik production is done by conducting trials to produce a new sigma value. The trial of production results was carried out by sampling for 30 days of observation to see whether or not there was a change in the sigma level and the number of defective products produced. The results of the solution implementation are then compared with the performance baseline that has been measured at the Measure stage. The results of the prototype adoption can be seen in the following table.

The results of the comparison of conditions before and after the implementation of the prototype system show a significant change in the level of defective products per month, DPMO performance, and sigma value. The level of defective products and performance has decreased, which then has an impact on increasing the sigma value in all production processes. The table above shows a significant improvement in the quality of products produced by the pattern formation and fixation processes. This result is largely due to the existence of comprehensive SOPs and guidelines regarding the selection of leaf material as the main raw material in the eco-printing process, which supports the achievement of the CTQ of these two processes. Meanwhile, in the scouring and mordanting process, the increase in sigma value was not significant enough, which was only 6.9%. This is due to the CTQ in the scouring and mordanting process focusing on fabric types that cannot be accommodated by the prototype system in this Six Sigma project. However, in general, the implemented solution is proven to provide significant quality improvement in eco-print products.

4. Conclusion

The quality of ecoprint batik with the application of Six Sigma and the application of Agile methods has proven to have a significant impact on the quality of ecoprint, as indicated by the sigma value at each stage in the process of making ecoprint products. In general, there is an increase in sigma value in two processes, namely pattern formation and fixation, with each sigma value increasing by 39.78% and 41.38%, respectively. Meanwhile, the sigma value in the scouring and mordanting process only increased by 6.9%. This is because the root cause of the quality of ecoprint batik has been identified through the Six Sigma method, namely the unavailability of standard SOPs and guidelines that regulate the steps of ecoprint workmanship, starting from determining the type of leaf as the main material. To adopt the agile nature of ecoprint batik production based on the root cause, a prototype system was created that can classify the types of leaves along with ways to produce ecoprints according to the type and nature of certain leaves, with relatively fast time and the right target. Based on the results of the analysis, this research also produces a framework as a standard that can be applied to ecoprint industry players. With this innovation, it is expected to increase the value of ecoprint batik with high quality as one of the largest trading commodities in Indonesia.

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