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MATERIAL BASED KNOWLEDGE AND CONCEPTUAL INQUIRY IN ECO PRINT PRACTICE FOR SUSTAINABLE FASHION

Mita Purbasari Wahidiyat[1]* and Hari Sulistiyowati[2]

[1]Graphic Design and New Media Program, School of Computing and Creative Arts, Bina Nusantara University, Jakarta, Indonesia, 11480
[2]Faculty of Mathematics and Natural Sciences Biology Department, Jember University, Jember, Indonesia

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Corresponding Author: Mita Purbasari Wahidiyat (mitawahid@binus.edu)

ABSTRACT

The environmental impact of the global fashion industry has intensified interest in plant-based textile practices that explore alternatives to synthetic dyeing processes. Eco print has emerged as a technique that transfers botanical forms onto textile surfaces using leaves, flowers, and other plant materials without synthetic chemicals. While previous studies have primarily examined eco print from technical or aesthetic perspectives, its role as a site of material-based knowledge production in textile design remains underexplored. This research examines eco print as a practice-based inquiry in textile design, focusing on how interactions between plant materials, textile surfaces, and embodied making processes generate design knowledge. Through the exploration of thirteen plant species with distinct morphological and pigment characteristics, the study investigates eco print as a sociomaterial practice in which designers and materials collaboratively shape visual outcomes. The analysis identifies four modes of material agency within eco print practice: resistive, expressive, structural, and cooperative. These forms of agency reveal how plant materials actively influence design processes, visual traces, and creative decision-making. The resulting textile artefacts are interpreted as epistemic objects that materialize knowledge about the relationships between plants, textile processes, and design practices. By positioning eco print as a material-based design inquiry rather than merely a natural dye technique, this research contributes to textile design discourse in three ways: first, by articulating eco print as a practice-based method of knowledge generation; second, by expanding discussions of material agency in plant-based textile processes; and third, by proposing a conceptual framework that situates eco print within sustainable and regenerative approaches to textile design.

KEYWORDS: Eco Print, Material Agency, Epistemic Object, Sociomateriality, Conceptual Framework.

1. INTRODUCTION

The global textile and fashion industry is known to be one of the sectors that has a great impact on the environment. Especially through the use of synthetic dyes, high water consumption, and the production of hazardous wastes (Lara et al., 2022). To address this challenge, various sustainable fashion approaches have emerged that aim to replace conventional production processes with more environmentally friendly techniques. One techniques that is increasingly attracting the attention of academics and design practitioners is eco print. Eco print is a technique for printing motifs on fabrics by utilizing botanical materials such as leaves, flowers, and other plant parts without using harmful synthetic chemicals (Šabarić et al., 2024).

Initial research on eco print is generally empirical and focuses on the technical and aesthetic aspects of the resulting prints. For example, eco -print techniques are studied in the context of creating motifs and colors of various fabric media as an environmentally friendly coloring alternative in fashion. Meanwhile, several other studies explore the use of eco print in creative education, the development of clothing products, as well as the aesthetic value generated by natural motifs (Wdyaningsih & Asiatun, 2024; Wika Watiningsih, 2022). However, most previous research has focused on the technical aspects of applying or evaluating the visual outcomes of eco print techniques, such as print quality or product creativity, without conceptually addressing how these practices contribute to design knowledge and the broader sustainability discourse. In this context, studies such as those conducted by Šabarić et al (2024) are trying to place a technique known as plant transfer printing (synonymous with eco print) as part of the eco design strategy in sustainable fashion that pays attention to aesthetic and ecological aspects (Šabarić et al., 2024). Another study states that eco print can also play an aesthetic approach that promotes ethical consumption and material innovation in contemporary textile design (Tessariol, 2025).

Within contemporary textile design research, there is growing interest in practice-based approaches that examine how knowledge emerges through direct engagement with materials, tools, and making processes. Textile practices such as natural dyeing, plant printing, and craft-based experimentation have increasingly been explored not only as sustainable production methods but also as forms of material inquiry that reveal the relational dynamics between designers, materials, and environments. In this context, eco print offers a particularly relevant case for investigating how textile practices generate knowledge through interactions with living materials such as leaves and flowers, whose pigments, structures, and responses to heat or pressure cannot be entirely controlled by the designer.

However, despite the growing interest in eco print within sustainable fashion, existing studies largely remain limited to technical performance and aesthetic outcomes. There is a lack of conceptual inquiry that positions eco print as a site of knowledge production. In particular, connections between eco print practice and theoretical frameworks such as new materialism, material agency, and design epistemology remain underdeveloped. This study addresses this gap by reframing eco print as a material-based epistemic practice. This context, the practice of eco print becomes relevant not because of the efficiency of the technique, but because of its attachment to specific materials and non-standardized processes. This research departs from the author's involvement with eco print practices involving thirteen plant species, each of which presents a different material character, visual response, and process uncertainty. This diversity of materials is not positioned as an experimental variable, but rather as a conceptual reflection basis to understand how material-based design practices can produce knowledge that is inseparable from the relationship between humans, materials, and the environment. Therefore, this research is designed to answer research directed at the following conceptual questions: (1) How can eco print be understood as a design practice that produces material-based epistemology in the context of sustainable fashion?; (2) How can the exploration of eco print through 13 species of plants be conceptualized as a sociomaterial relationship between humans, materials, and time processes in textile design?; What conceptual contribution can eco print offer to the discourse of sustainable design and fashion, particularly in the framework of material agency and epistemic objects?; In line with the research question, the objectives of this research are: (1) To develop a conceptual framework that positions eco print as a material-based design practice that produces knowledge, not just natural dyeing techniques; (2) Articulating the role of plants as non-human actors in the practice of eco print, by utilizing the exploration of 13 plant species as conceptual anchors to read material agency; (3) Offering a new theoretical reading of eco print in the context of sustainable fashion through the integration of

perspectives of new materialism, sociomateriality, and epistemic objects. These research questions guide both the methodological approach and the analytical framework developed in this study.

This paper is structured as follows. The next section reviews relevant literature on eco print, material agency, and sociomaterial design. The methodology section outlines the conceptual and practice-based approach adopted in this study. The results and discussion section presents the analysis of eco print practices through thirteen plant species, followed by the development of a conceptual framework. Finally, the conclusion summarizes the theoretical contributions and implications for sustainable fashion and design studies.

Thus, the expected contribution from this research not only adds to the empirical literature on eco print techniques, but also has its contribution theoretically, methodologically, and conceptually, as well as the discourse of sustainable and regenerative fashion. This research makes a theoretical contribution by: (1) Repositioning eco print from technical or decorative practice to epistemic practice in design and fashion studies; (2) Expanding the application of the concept of material agency in the context of plant-based textile design, which has rarely been explicitly discussed in the eco print literature; (3) Integrating eco print into the discourse of epistemic objects, by showing how prints and processes function as a medium for the production of design knowledge. Thus, this paper enriches design studies and fashion theory through a conceptual approach based on material practices. Although it does not claim to be practice-based research in a formal methodological sense, it shows how design practice can serve as a source of conceptual reflection. This contribution lies in: (1) The use of eco print practices as a thinking device; (2) The use of material exploration as the basis for conceptual argumentation; and (3) Placement of visual documentation as a visual argument, not an illustration. This approach is relevant for design researchers who work between practice and theory. This research also contributes to the discourse of sustainable fashion by: (1) Criticizing sustainable fashion approaches that focus too much on efficiency and material substitution; (2) Offering eco prints as examples of design practices that emphasize the ethical relationship between people, materials, and the environment; (3) Opening up space for the understanding of fashion as a regenerative practice based on local attachment, temporality, and diversity of biological materials.

2. LITERATURE REVIEW

The study of eco print in textile design to date has been mostly limited to technical aspects, visual aesthetics, and its use as a natural dye method. This is as done by Ningtarich et al., (2025) who evaluated the quality of eco print in various types of fabrics focusing on aspects of color performance against washing and color aging, without positioning eco print as a phenomenon that opens up theoretical discourse in textile design (Ningtarich et al., 2025). On the other hand, there are studies that are beginning to include eco prints at a broader level of design practice, such as showing how eco prints combine botanical aesthetics with sustainability innovation and ethical consumption in contemporary textile design (Tessariol, 2025). The study conducted by Tessariol (2025) highlights eco print as an aesthetic effort that opposes the homogeneity of mass production by producing unique patterns that highlight the relationship between natural materials and ecological values.

In the study of contemporary design and materials, an important shift in thinking began to emerge: materials are no longer passive entities that only wait for human instruction, but are seen as actors in the process of producing design knowledge. This shift is often referred to as material turn or new materialism, and is relevant for eco print because the way eco print works is not just a coloring technique, but as a result of negotiations between humans and plant materials that produce unique patterns, colors, textures, and experiences.

In the tradition of new materialism, materials are understood as forms of non-human agency that impact the design process. It is not just a tool executed by humans. Anneke Smelik, in her study "New Materialism: A theoretical framework for fashion in the age of technological innovation" underlines that material agency involves a shift from human agency to matter, where fabrics, fibers, and other materials are not only objects. But it's part of the entangled assemblages that come together to shape meaning, form, and experience in fashion practice (Smelik, 2018). Through Smelik's thought, it can be emphasized that in the context of eco print, plants are not just dye materials but entities that offer material inputs, process contingencies, and aesthetic outputs that are unique and cannot be completely predicted. Eco print thus opens up space for material human entanglements that expand the understanding of design beyond a centrally human hierarchy.

The concept of epistemic objects provide a strong theoretical foundation for reading eco print as a practice that produces knowledge, not a product.

Epistemic objects are defined as objects that are "incomplete and always open to the dialogue of knowledge" that combine material and conceptual components in the interaction of sociomaterial design practices (Beltagui et al., 2023). The sociomateriality approach emphasizes that design objects (including raw materials) and social practices are inseparable in the production of knowledge and meaning in design. In this framework, eco prints function as epistemic objects that connect plant materials, practical processes, designer experiences, and conceptual knowledge about sustainability. Eco print produces negotiated knowledge that arises from direct interaction between humans and plant materials, not soley from technical techniques alone.

The view of sociomateriality associated with epistemic objects thinking is also relevant because it rejects the firm separation between social and material aspects in design practice. Sociomateriality sees practice as a continuous chain in which materials, technology, social values, and knowledge do not stand apart, but are intertwined in the process of knowledge and creation (Beltagui et al., 2023). In the context of eco print, the sociomaterial framework allows us to explain how: (1) Materials (plants) and design actions co-produce aesthetic and conceptual outputs; (2) The material is not only selected or designed, but (acted with); (3) Each plant presents a unique ambiguity and history. This is a sign that eco print is not just a technique, but an epistemic praxis.

When eco print is understood through this lens, the practice of eco print is no longer limited to natural dyeing techniques but: (1) It is a dialogue material, not just a material application; (2) Presenting materials as active participants in the production of design knowledge; (3) Connecting ecological and aesthetic aspects through material-human entanglement dynamics; (4) Challenging the paradox between rapid industrial production and sustainable production produced through high-variation artisanal processes. Several empirical design studies indicate the importance of understanding materials as active agents in contemporary design practice, although they have not been specifically applied to the textile eco-print concept (Neubauer, 2022).

Eco print practices can also be situated within the broader discourse of contemporary textile craft, where designers engage directly with natural materials to explore alternative relationships between making, environment, and material knowledge. In recent years, textile practitioners have increasingly turned to plant-based printing techniques as a way to reconnect design processes with ecological cycles and local material resources. Within this context, eco print operates not only as a decorative or technical procedure, but as a form of material exploration that foregrounds the unpredictability and variability of living materials. The marks produced through eco print therefore become records of interaction between botanical matter, textile surfaces, and embodied gestures of making. This perspective aligns eco print with a wider movement in textile design research that values craft-based experimentation, material sensitivity, and process-oriented knowledge production.

3. RESEARCH METHODS

This research uses a conceptual qualitative approach with an orientation to conceptual inquiry in design studies. Instead of testing hypotheses or evaluating technical performance, this study aims to develop a theoretical understanding of eco print as a material-based design practice that produces knowledge (material-based epistemology). This approach places design practice not as an object of measurement, but rather as a site of conceptual reflection. Thus, this research aligns with the tradition of theory-building in design studies, which utilizes practice as a source of critical thinking and conceptual articulation (Beltagui et al., 2023; Smelik, 2018).

In this study, the practice of eco print is positioned as the main locus of knowledge production, where artistic processes not only function as a medium of visual expression, but also as a means to understand the material relationship between plants, printing techniques, and textile surfaces. The practice-based research approach allows practice to be treated as a form of reflective inquiry, in which artistic decisions (from material selection to visual outcomes), become part of the construction of knowledge itself.

The selection of thirteen types of plants as the main source of eco print practice is an integral part of the position of the practice in this study. These plants include fern leaves (Nephrolepis exaltata), eucalyptus leaves (Melaleuca cajuputi), mahogany leaves (Swietenia macrophylla), cassava leaves (Manihot esculenta), guava leaves (Psidium guajava), kalpataru or jabon leaves (Nauclea cadamba), kebo ketepeng leaves (Senna alata), finicilin leaves (Jatropha multifida Linn), red castor leaves (Jatropha gossypiifolia), cocoa leaves (Theobroma cacao), mango leaves (Mangifera indica), teak leaves (Tectona grandis), and waru flowers (Hibiscus tiliaceus). These thirteen plants are not treated as mere decorative objects, but rather as

epistemic materials that carry their respective biological, visual, and ecological characters. Each leaf has a different morphological structure, fiber thickness, pigment content, and chemical response to mordanting and heating, resulting in a variation in visual traces that are not entirely predictable.

Thus, the practice of eco print in this study does not aim to achieve uniform or technically optimal print results, but rather to explore how different plant characters affect the formation of images, colors, and textures in fabrics. The thirteen plants form a framework of practice that allows for comparative reading between materials, while also opening up space for reflection on the relationship between nature, the textile production process, and practice-based knowledge. This position of practice also affirms that the knowledge produced is not solely verbal or conceptual, but is manifested through visual artifacts, color residues, print failures, and variations in results arising from the direct interaction between the artist's body, plant materials, and eco print techniques. In this way, practice is not placed as a theoretical illustration, but rather as a field of research itself, in which thirteen plants serve as the main node that connects ecological aspects, materiality, and artistic practice within the framework of practice-based conceptual research.

The development of the concept in this study proceeds through three main stages. First, the reflection stage of material-based practice. A systematic reflection was conducted on long-term engagement with eco print practices, focusing on how plant materials respond to the printing process, produce visual variation, and influence design decision-making. This reflection is not expressed in the form of a technical procedure, but rather as a basis for conceptual thinking. Second, dialogue with theoretical literature. Reflection on practice is then positioned in a critical dialogue with the literature related to new materialism, material agency, sociomateriality, and epistemic objects in the study of design and fashion. Literature is not used as a normative framework, but rather as a tool to interpret and expand the meaning of eco print practices. Third, articulation of conceptual propositions. From the interaction between practice and theory, this study formulates a conceptual proposition that explains eco print as a design practice that produces material-based knowledge. This proposition serves as the basis for the conceptual framework proposed in the research.

Visual documentation in the form of eco print results and plant material traces is used as a conceptual visual argument, not as empirical data that is quantitatively analyzed. Visuals are understood as parts of epistemic objects that represent processes, show material uncertainties, and trigger theoretical reflection. Thus, visuals do not function as mere aesthetic illustrations, but rather as a medium of articulation of design knowledge.

The eco print explorations in this study were conducted as part of an ongoing textile design practice focused on plant-based printing methods. The experiments were carried out using natural fibre textiles, primarily cotton fabrics, selected for their ability to absorb plant pigments effectively. Eco print was performed through a bundle-dye technique in which plant materials were arranged directly on the textile surface, rolled or folded, and then subjected to steaming processes to transfer pigments and botanical imprints onto the fabric. This practice-based exploration was not intended to achieve standardized dyeing results but to investigate how different plant materials interact with textile surfaces and printing processes. The variations in pigment release, imprint clarity, and structural traces produced during the steaming process became the primary basis for reflecting on the relationships between plant morphology, textile techniques, and embodied design decisions.

Daun Pakis	***Daun Kayu Putih***	***Daun Mahoni***
(Nephrolepis exaltata)	***(Melaleuca cajuputi)***	***(Swietenia macrophylla)***
		
Daun Ubi Kayu	***Daun Jambu***	***Daun Kalpataru / Jabon***
(Manihot esculenta)	***(Psidium guajava)***	***(Nauclea cadamba)***

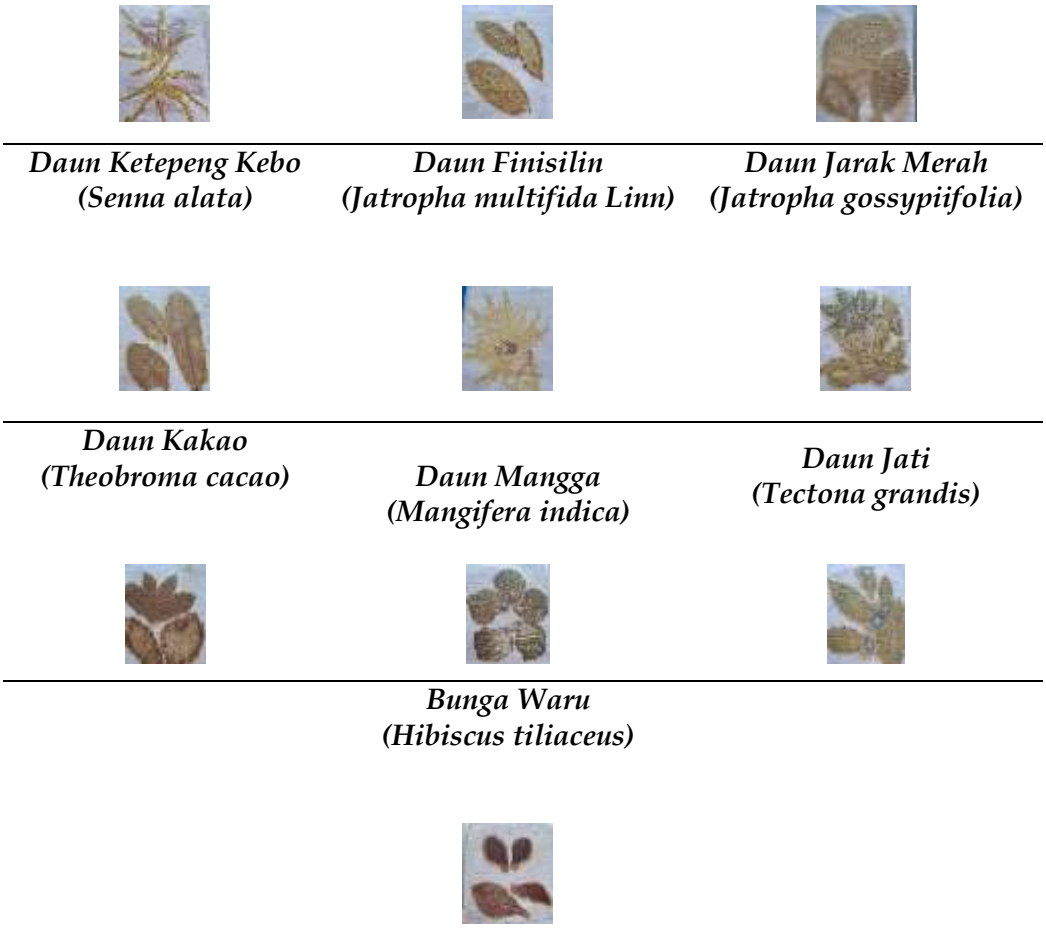

Figure 1. Eco print of the thirteen plants used.

As a conceptual paper, this research has deliberate limitations. This study: (1) It does not aim to produce findings that can be replicated industrially; (2) Not claiming the technical validity or efficiency of the eco print method; (3) and is not intended as a practical guide. The main focus of the research is conceptual contributions, not empirical generalizations.

The practice-based conceptual approach used in this study is relevant for the study of design and fashion because it allows the exploration of aspects that are difficult to measure technically, such as material relations, ethical values, and the production of meaning. Thus, this method aligns with the research objective of expanding the theoretical discourse on sustainable textile design through eco print practices.

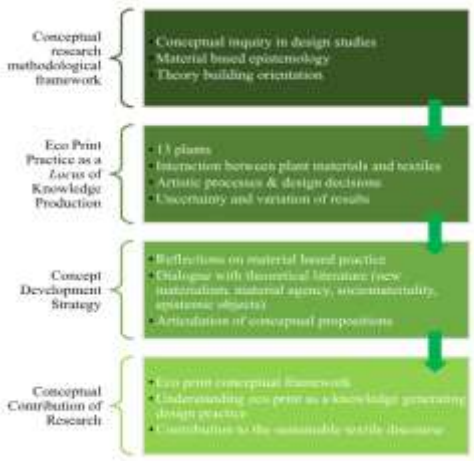

Figure 2. Conceptual methodological framework.

4. RESULTS & DISCUSSION

This section addresses the research questions by examining how eco print practice generates material-based knowledge through interactions between plant materials, textile processes, and embodied design practices. The selection of thirteen plant species in this study also reflects the diversity of botanical materials that can be engaged within eco print practices. Different plants possess distinctive morphological structures, pigment compositions, and chemical responses that influence the way their traces appear on textile surfaces. Variations in leaf thickness, vein structures, pigment intensity, and moisture content all contribute to differences in how pigments are transferred during steaming processes. By working with multiple plant species rather than a single material, the exploration allows a broader

understanding of how material diversity shapes the visual and conceptual outcomes of eco print practice. This diversity also highlights the importance of material sensitivity in textile design, where each plant introduces its own possibilities and limitations within the printing process.The exploration of thirteen plant species in eco print practice is not intended to identify the 'best' crop. Rather, it is to read how each material produces a different form of agency, thus positioning eco print as an epistemic design practice.

Table 1: Plants as conceptual anchors.

No.	Plant Species	Visual Trace & Material Agency	Practical Relation & Epistemic Function
1	Fern Leaf *(Nephrolepis exaltata)*	Repetitive vein structure and structural expressive	The body follows the rhythm of the leaf; material as pattern generator
2	Cajuput Leaf *(Melaleuca cajuputi)*	Fain imprint and resistive	Technique dominates, knowledge emerges from limitation
3	Mahogany Leaf *(Swietenia macrophylla)*	Strong, thick pigment, and dominant	Material drives outcomes and material as primary actor
4	Cassava Leaf *(Manihot esculenta)*	Radial veins and cooperative	Balanced collaboration and stable human material relation
5	Guava Leaf *(Psidium guajava)*	Firm silhouette and performative	Replicable technique and epistemic reference object
6	Jabon Leaf *(Neolamarckia cadamba)*	Wide texture and performative	The body experiments and material opens possibilities
7	Candle Bush Leaf *(Senna alata)*	Elongated organic traces and adaptive	Customized technique and situational knowledge
8	Finisilin Leaf *(Urtrophia multifida Linn.)*	Complex, unstable pattern, and ambiguous	Intense negotiation and unfinished epistemic object
9	Red Jatropha Leaf *(Jatropha gossypifolia)*	Strong but uneven pigment and resistive expressive	Friction in practice and knowledge through failure
10	Cacao Leaf *(Theobroma cacao)*	Intense color and cooperative	Synchronous body and technique and material as partner
11	Mango Leaf *(Mangifera indica)*	Gradual color layering and gradual agency	Layered process and temporal knowledge
12	Teak Leaf *(Tectona grandis)*	Strong pigment and dominan resistive	Material resists control and critique of design determinism
13	Sea Hibiscus Flower *(Hibiscus tiliaceus)*	Intense pigment and affective	Bodily sensitivity and taste based knowledge

Through reading thirteen plant species, this study shows that the practice of eco print does not produce a single form of knowledge. Rather, it is a spectrum of epistemic relations formed by material agency, bodily responses, and technical negotiation.

The main results of this study show that the practice of eco print cannot be understood solely as a natural dyeing technique, but rather as a site of material-based knowledge production. Through practical engagement with thirteen plant species. Eco print serves as an epistemic process in which knowledge is not generated through mere theoretical abstraction, but through direct interaction between the designer's body, plant materials, printing techniques, and textile surfaces. An exploration of fern leaves, teak leaves, mango leaves, and waru flowers shows that each material presents a distinct state of knowledge. Knowledge in a situated context, arises from concrete experience, and cannot be completely reduced to a technical principle by the universal. These findings reinforce the view that in design studies, practice can function as a mode of inquiry, rather than just an application and theory stage (Beltagui et al., 2023; Smelik, 2018). Thus, the results of this study affirm eco print as a design practice that generates knowledge through process, rather than the optimization of the final result. This is in line with the first goal of the research, which is to develop a conceptual framework that positions eco print as an epistemic material-based design practice. These findings directly respond to the first research question by demonstrating that eco print functions as an epistemic practice rather than merely a technical method.

Through the exploration of eco prints using thirteen types of plants, this practice demonstrates how plant materials play an active role in shaping the visual results and meaning of design. The results of the eco print showed a significant variation in visual footprints, both in terms of color intensity, sharpness

of motifs, and transformation of leaf shapes on textile surfaces. These variations are not entirely controllable by the designer, but rather arise from the complex interaction between the morphological structure of the leaves, the content of natural pigments, the mordanting process, and heating conditions. Thus, the results of this practice confirm that eco print is not a mechanical reproductive process, but rather a practice that relies on constant negotiation between design intent and material response. In this context, the results of eco print practices function as epistemic traces or material traces that store knowledge about plant behaviour during the textile printing process. This knowledge does not exist in the form of quantitative data, but is manifested through color residues, motif distortions, image transfer failures, and visual instability that are the source of conceptual reflection.

One of the main conceptual results of this eco print practice is the strengthening of the idea of material agency. Plants in eco print practice do not function as passive materials that are subject entirely to the will of the designer, but rather demonstrate the capacity to "act" through their material's response to the printing process. Each type of leaf exhibits different behavioral tendencies, both in pigment release, resistance to heat, and the way the bone structure of the leaf is recorded on the fabric.

Uncertainties that arise in the eco print process such as inconsistent color variations or fragmented motifs are not positioned as design failures, but rather as an inherent part of material relationships. These findings are in line with the thinking in the new materialism which rejects the anthropocentric view of the material, and places the material as an entity with relational capacity in the process of production of meaning (Bennett, 2010; Peacock, 2010).

Thus, the results of this practice show that eco print can be understood as an arena of meeting between human and non-human agency, where design results emerge from co-production that are not entirely predictable. This perspective expands the understanding of eco print from a mere eco-friendly textile technique to a design practice that challenges the paradigm of control and efficiency in fashion production.

Building on these findings, the following section develops a conceptual framework that synthesizes the identified material relations, epistemic processes, and forms of material agency. Meanwhile, based on the reflection of eco print practices involving thirteen species of these plants, this study identifies that material agency is not present singularly or homogeneously. On the contrary, plants as living materials show various modes of agency that affect the course of practice, visual results, and the process of knowledge production. Material agency in this context is understood not as intentionality, but as a material capacity to shape, direct, limit, or disrupt human design practices. Barad's (2007) perspective shows that agency is not a passive attribute of matter but a re-enactmnent that occurs through intra-action between humans and material (Fox, 2020). In addition, Bennett suggested that material has thing power , namely the ability to influence the results of practice in its own way (Bennett, 2010). In the context of eco print, resistive agency, expressive agency, structural agency, and cooperative agency built on the theoretical logic of Barad (2007) and Bennet (2020) constitute several modes of material agency that are directly seen in the visual response and work process of the thirteen plants explored. This typology is not intended as a technical or botanical classification, but rather as an analytical framework for reading how plant materials play a role as non-human actors in the production of practice-based knowledge.

Resistive agency refers to the condition when plant materials show a tendency to resist or interfere with human design intentions. In the practice of eco print, this form of agency appears when leaves do not transfer pigment optimally, produce fragmented motifs, or exhibit visual instability despite the techniques being applied relatively consistently. The finicil leaves (Jatropha multifida) and the red castor leaves (Jatropha gossypiifolia) exhibit a strong form of resistive agency. The complex structure of the leaves and unstable pigment responses create prints that are difficult to predict and often do not match the designer's initial expectations. Instead of being considered a technical failure, this condition is treated as an epistemic moment, in which knowledge arises precisely from the tension between human intent and material response. From the perspective of new materialism, resistive agency asserts that materials have the capacity to "say no" to the logic of control and optimization. Bennett (2010) calls this phenomenon thing-power, which is material power to influence human actions (Bennett, 2010). Thus, material resistance in eco print is not an obstacle, but a critical mechanism that opens up reflection on the assumption of human dominance in design practice.

Expressive agency arises when plant materials demonstrate the capacity to produce a strong and dominant visual imprint, often surpassing or even shifting the designer's aesthetic intentions. In these conditions, the material not only responds to the technique, but also actively shapes the visual

narrative of the artifact. Teak leaves (Tectona grandis), mahogany leaves (Swietenia macrophylla), and waru flowers (Hibiscus tiliaceus) show expressive agency through color intensity, morphological structure readability, and imprint strength on fabrics. The artifacts produced from these plants show that the visual is not entirely "designed", but rather is produced through co-production between material and practice. In the context of epistemic objects (Knorr Cetina, 2001), eco print artifacts with high expressive agency serve as objects that continue to "speak" and trigger reinterpretation. Material in this case can be understood as a co-author, which also determines the direction of meaning and aesthetics. These findings reinforce the argument that in the practice of material-based design, knowledge does not come from full control, but rather from openness to the expressive capacity of materials.

Structural agency refers to the condition in which the biological and morphological structure of plants, such as leaf veins, fiber thickness, and surface shape directly directs the visual composition of the eco print. In this form of agency, the material structure is the main factor that limits as well as shapes visual possibilities. Fern leaves (Nephrolepis exaltata), mango leaves (Mangifera indica), and kalpataru or jabon leaves (Nauclea cadamba) show how the natural patterns of the leaves inherently determine the rhythm, direction, and visual density of the fabric. Although the techniques used are similar, the prints show significant variations due to differences in material structure. The structural agency emphasizes that design in eco print is not the process of creating shapes from empty space, but the process of corresponding to existing structures (Ingold, 1996). In this context, designers do not "design forms", but respond to and negotiate the biological structure of the material. The knowledge produced is embodied and relational, born from direct involvement with material morphology.

Cooperative agency arises when plant materials show a relatively stable and consistent response to the eco print process, allowing designers to build comparative reads between materials. This form of agency does not show visual dominance or extreme resistance, but rather presents cooperative working conditions. Guava leaves (Psidium guajava), cocoa leaves (Theobroma cacao), and cassava leaves (Manihot esculenta) exhibit cooperative agency through fairly consistent pigment transfer and recognizable motif structure. These plants are not positioned as "the most successful", but rather as epistemic reference points that help to read the differences in the characteristics of other materials. In the framework of sociomateriality, cooperative agency allows the practice of eco print to be understood as a network of relationships that are stable but still open to variation (Orlikowski, 2007). Cooperative materials serve as boundary markers, which precisely clarify how resistive, expressive, and structural agency work relationally.

The typology of material agency proposed in this study reinforces the conceptual framework that positions eco print as a material-based design practice that generates knowledge. By reading thirteen plants as nonhuman actors with different forms of agency, this study shows that design knowledge is not single, linear, or completely controllable. Resistive agency affirms the role of failure as a source of knowledge. Expressive agencies show material as co-authors. Structural agency highlights the co-production of forms. And cooperative agencies allow relational reading between materials. The four form a spectrum of agencies that place eco print as an epistemic practice that is in line with the principles of sustainable fashion, slow fashion, and regenerative design. Thus, this typology serves not only as a tool for analyzing eco print practices, but also as a theoretical contribution to the study of design and fashion, particularly in understanding how material-based practices can generate knowledge that is more than human in nature.

The results of eco print practice in this study also strengthen the position of eco print as an epistemic object, namely an object that is open, unstable, and continues to develop along with the research process. The resulting eco print artifacts are not intended as a final product, but rather as a medium for reflection that promotes conceptual questions about materiality, sustainability, and the relationship between humans and nature in textile design.

The visual documentation (Figure 1) of the eco print results serves as a conceptual argument that enables critical reading of the process and the results of the practice. Visuals not only represent aesthetics, but also capture the tension between design intent and material resistance. In this case, eco print serves as a means to articulate knowledge that is difficult to express through verbal language alone, as affirmed in the tradition of practice-based research in art and design (Candy & Edmonds, 2018; Sullivan, 2009).

Through this understanding, eco print can be positioned as a design practice that generates material-based knowledge, as well as a reflective method to examine sustainability issues from a more relational and non-instrumental perspective.

Based on the reflection of eco print practices, theoretical dialogue, and conceptual analysis discussed in the previous section, this study offers a conceptual framework to understand eco print as a material-based design practice that generates knowledge. This framework is not intended as a procedural model or technical guide, but rather as a conceptual tool for reading the relationships between materials, practices, and the production of meaning in sustainable textile design.

The conceptual framework proposed consists of four main elements that are intertwined: (1) plant material as epistemic agent, (2) eco print practice as relational site, (3) material uncertainty as a source of knowledge, and (4) visual artifact as epistemic objects.

First, plant materials are positioned as epistemic agents that have the capacity to influence design processes and results. In this framework, leaves and flowers are not understood as passive materials, but rather as entities that carry biological characters, pigments, and structures that actively form the visual traces of the eco print. This understanding shifts the designer's position from a full controller to a participant in material relations. Second, the practice of eco print is understood as a relational site where knowledge is produced through the interaction between designers, plant materials, printing techniques, and time. This practice serves as a space of reflective inquiry that allows for the exploration of the values, ethics, and meaning of sustainability through process, rather than solely through the end result. Third, material uncertainties manifested in color variations, motif distortions, and transfer failures are positioned as sources of knowledge, not as errors that must be eliminated. Within this conceptual framework, uncertainty becomes an indicator of living material relations and opens up space for critical reflection on design paradigms that emphasize control and efficiency. Fourth, visual artifacts resulting from eco prints are understood as epistemic objects that function as a medium for articulating design knowledge. These artifacts are not final or stable, but rather continue to spark new questions and interpretations as they engage in theoretical discourse and design practice.

Overall, this conceptual framework positions eco print as a design practice that is not only relevant in the context of material sustainability, but also significant as an epistemological approach in the study of design and fashion. This framework allows researchers and practitioners to read eco print as a material-based knowledge production process that challenges the boundaries between practice and theory.

Figure 3: Conceptual framework of eco print as a material-based design practice.

This diagram visualizes the conceptual framework that research offers for understanding eco print as a material-based design practice that generates knowledge. By placing the practice of eco print at the center, this diagram confirms that it does not serve as a theoretical illustration, but rather as a primary locus of knowledge production. The elements surrounding the practice are arranged in circular relationships to show that the production of knowledge in eco print is relational, non-linear, and takes place through continuous feedback between materials, bodies, techniques, and visual artifacts.

The position of eco print practice in the middle of the diagram confirms the practice-based research approach, where practice is understood as a form of reflective inquiry (Candy & Edmonds, 2018; Sullivan, 2009). Practice is not reduced to technical procedures, but rather is treated as a conceptual space where knowledge is generated through direct engagement with the material. Thus, eco print is positioned as a process of thinking through making, not just a textile production activity.

Material elements as Epistemic Agents show that plants, such as leaves and flowers, have an active role in shaping the results and meaning of eco print practices. This concept aligns with the idea of new materialism and material agency which rejects the view of the material as a passive entity (Bennett, 2010; Peacock, 2010). In the context of eco prints, plant materials carry biological characters, pigments, and morphological structures that are not completely controllable by the designer. Thus, materials contribute directly to the production of knowledge through their response to the printing process.

The elements of the relationship between practice, body, and technique emphasize that knowledge in eco print does not lie in technique alone, but in the relationship between the designer's body, work gestures, decision-making, and the technique used. The body is understood as a mediator that bridges design intent and material response. This perspective is in line with the approach to sociomateriality in design studies, which sees practice as the result of the intertwining between people, tools, and materials, rather than as isolated individual actions.

The element of uncertainty as knowledge is one of the main conceptual contributions of this framework. Uncertainties manifested in color variations, motif distortions, or transfer failures are positioned not as errors, but as sources of knowledge. This challenged the modernist design paradigm that emphasized control, reproducibility, and efficiency. Within this framework, uncertainty is understood as an indicator of living material relationships and as a trigger for conceptual reflection on sustainable design practices.

The element of visual artifacts as epistemic objects shows that the results of the eco print and its visual documentation function as a medium of articulation of design knowledge. Referring to the concept of epistemic objects (Knorr Cetina, 2001), visual artifacts are understood as objects that are open, not final, and constantly raise new questions. Eco print artifacts are not intended as stable end products, but rather as a means of reflection that allows dialogue between practice and theory.

Thus, the circular structure in this diagram has an important epistemological meaning. The relationship between elements is not hierarchical or linear, but rather shows that the production of knowledge in eco print takes place through a continuous back-and-forth process between practices, materials, reflections, and visual artifacts. Thus, this framework affirms that design knowledge is situational, relational, and based on material experience. Overall, this conceptual framework integrates thirteen plant-based eco-print practice data with new materialism theory, practice-based research, and epistemic objects to respond to sustainability problems in textile design. This framework affirms that eco print can be understood as a design practice that generates material-based knowledge, as well as a critique of the exploitative and reductionist paradigm of fashion production. Thus, this framework not only explains how eco print is done but also why eco print is relevant as a conceptual approach in sustainable design and fashion discourse.

The discussion of the results of this study shows that the main contribution of the research does not lie in the technical innovation of eco print, but in the expansion of the conceptual framework in understanding sustainable textile design. By focusing on material relations and plant agency, this research challenges sustainability approaches that tend to focus on material efficiency, optimization, and performance.

On the other hand, eco print in this study is understood as a reflective and ethical design practice, where uncertainty and material limitations are part of the value of the design itself. This perspective is relevant to the critique of the industrial paradigm in sustainable fashion, which often reproduces the logic of rapid production and material control, despite using an eco-friendly narrative (Fletcher & Grose, 2012; Smelik, 2018). Thus, the results and discussion of this study propose eco print as an alternative approach for sustainable textile design. Not as a single technical solution, but as a conceptual practice that drives a change in the way we think about materials, processes, and the human relationship with nature.

Overall, the results of this study confirm that the practice of eco print based on thirteen local plants can function as a means of producing design knowledge that is conceptual and reflective. Through this practice, eco print is positioned as an epistemic field that uncovers the complex relationships between plant materials, printing techniques, and design meanings. The conceptual implications of this research open up opportunities for the development of design and fashion studies that are more sensitive to materiality, uncertainty, and sustainability ethics. By placing practice as the main source of theoretical thought, this research contributes to the strengthening of the practice-based research approach as a legitimate and relevant strategy in the development of contemporary design theory.

The findings of this research suggest that eco print can be understood not only as an environmentally friendly textile technique but also as a methodological approach for material exploration in textile design practice. By engaging directly with plant materials, designers are encouraged to work with the inherent variability of pigments, structures, and biological responses rather than attempting to fully control them. For textile designers and researchers, eco print provides a framework for experimenting with plant-based materials as active participants in the design process. This approach opens opportunities for developing textile practices that emphasize material sensitivity, process-based learning, and ecological awareness. In this sense, eco print contributes to broader discussions in textile

design research about how sustainable practices can be integrated with material inquiry and creative experimentation. Beyond its role as a material exploration, eco print also invites reflection on the future directions of sustainable textile practices. In contrast to industrial dyeing systems that prioritize uniformity and efficiency, eco print emphasizes variability, locality, and process-based making. This shift in perspective encourages designers to reconsider the relationship between textile production and ecological systems. Rather than treating nature as a resource to be controlled, eco print practices foreground collaboration with living materials whose behaviors cannot be fully predicted. Such an approach resonates with emerging discussions on regenerative design and slow fashion, where sustainability is understood not only through material substitution but through a transformation of how designers engage with materials, time, and environmental processes

5. CONCLUSION

This study emphasizes that eco print is not just a natural coloring technique, but is a material-based design practice that produces knowledge (material-based epistemology). Through the exploration of thirteen plant species, the study shows that each material carries unique biological, visual, and process characterisitcs, which actively influence the designer's interactions, techniques, and visual outcomes. Thus, design knowledge does not arise from complete control over materials, but from the dynamic interaction between humans and materials, answering the first question of research regarding how eco print can be understood as an epistemic practice in the context of sustainable fashion. Material exploration also reveals that the interaction between designers, plants, and the printing process can be conceptualized as sociomaterial relations. The variation in material response, process uncertainty, and visual footprint formed shows that the practice of eco print is an arena of knowledge co-production, where the designer's body, printing technique, and material character influence each other. Thus, this study confirms the answer to the second question, namely, the practice of eco print through thirteen plant species, showing how the relationship between humans, materials, and time shapes situational, contextual, and non-linear design knowledge.

In addition, this study shows that eco print makes a conceptual contribution to the study of sustainable design and fashion, particularly through the lens of material agency and epistemic objects. The resulting visual artifacts are not just the final product, but rather a medium of theoretical reflection that raises questions about sustainability, materiality, and design ethics. Eco print challenges the fashion industry's paradigm that emphasizes control, efficiency, and homogeneity, and offersing an alternative in regenerative design practices that value material diversity, temporality, and local attachments. Thus, this study also answers the third question about the conceptual contribution of eco print to the discourse of design and fashion theory.

Overall, this study shows that eco print: (1) Functions as a site for material-based knowledge production, where experience, material response, and printing processes produce unique knowledge and lies in the relationship between humans and materials; (2) Affirming sociomaterial relations as the core of design practice, where plant agency and material uncertainty are a source of reflection and learning; (3) Make a theoretical contribution to the study of sustainable design and fashion, by placing eco-print artifacts and processes as epistemic objects that open up space for the discussion of design concepts, values, and ethics.

In other words, eco print expands the understanding of design from a mere production technique to an epistemic practice that is conceptually, methodologically, and ethically relevant, while offering a new perspective for the study of sustainable and regenerative fashion. This study positions eco print not only as a sustainable textile technique but as a critical epistemological approach in contemporary design research.

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