

Biomimicry in Textile Design: Rafflesia-Inspired Pattern Development from Royal Belum

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ABSTRACT

Textile design faces the challenge of balancing ecological responsibility with creative innovation, particularly in the development of sustainable patterns inspired by nature. This study addresses this issue by investigating how biomimicry, through the imagery of the Rafflesia flower in Malaysia's Royal Belum

Rainforest, can inform ecologically responsible textile design. A qualitative visual methodology was employed, using high-resolution photographic documentation as the primary data source. Photography served not only to capture intricate textures, colours and structures but also to mediate their translation into design. A total of 150 photographs were captured in situ and analysed using the Qualitative Colour Pattern Analysis (QCPA) framework. The analysis revealed an unexpected dominance of warm-toned segments and striking radial symmetry, both of which became central design drivers. These insights guided the creation of eight textile patterns, four abstract stylisations and four literal botanical motifs. Findings demonstrate that photography, when integrated with QCPA, deepens designer engagement with ecological subject matter and generates patterns that embody both aesthetic richness and environmental symbolism. The study contributes a replicable visual analysis process for bioinspired textile design. It advances Sustainable Development Goal 15: Life on Land while offering pathways for culturally resonant, ecologically responsible and commercially adaptable textile practices.

Keywords: *Biomimicry, Biological Imagery, Photography as Visual Tool, Qualitative Colour Pattern Analysis (QCPA), Textile Design*

INTRODUCTION

Textile design today faces the dual challenge of fostering creative innovation while meeting urgent ecological responsibilities. Within this landscape, biomimicry has emerged as a strategy for translating nature's time-tested solutions into sustainable design applications. Studies have shown that patterns and colours observed in butterfly wings, animal skins and plant surfaces can be adapted into textiles to enhance both aesthetics and performance (Cabral et al., 2024). Cabral et al. emphasise how these biological themes generate distinctive patterns aligned with sustainable principles, while Subash and Perumalsamy (2023) highlight the potential of biomimetic structures to improve material longevity and environmental efficiency. Kapsali et al. (2024) explore the influence of such textiles on consumer perception, pointing to growing market demand for sustainable biomimetic designs.

Despite this progress, several challenges remain. Much of the existing research relies on widely documented biological models such as lotus leaves, spider silk, or gecko adhesion (Das & Martinez, 2019), leaving locally significant flora and fauna underexplored as design references. Garg (2024) calls for deeper investigation into real-world biomimicry applications that address both scalability and cultural relevance. Lecointre et al. (2023) stress that integrating biological motifs in textile design can simultaneously foster creative expression and ecological responsibility, yet few methodologies systematically bridge natural observation with design practice. Furthermore, although photography is a common tool for documentation, its structured role as a mediating instrument for transforming ecological imagery into design-ready visual data has not been thoroughly examined.

This study responds to these gaps by focusing on Malaysia's Rafflesia flower, a rare and culturally iconic parasitic plant from the Royal Belum Rainforest. The Rafflesia is biologically unique: it possesses a radial petal structure, striking surface textures and warm, saturated hues that make it visually compelling for design interpretation. Beyond its aesthetic appeal, Rafflesia carries cultural and environmental significance as a national symbol and a vulnerable species, offering a meaningful opportunity to align textile innovation with biodiversity awareness and conservation goals.

Photography serves as the central tool in this research, not merely to document but to analyse and interpret the flower's intricate forms. By employing a qualitative visual methodology grounded in the Qualitative Colour Pattern Analysis (QCPA) framework, the study systematically extracts design-relevant information from high-resolution, in situ photographs. These visual data are translated through a staged

workflow that includes observation, sketching, stylisation and pattern development. This process results in textile prototypes that embody both natural inspiration and creative transformation.

Accordingly, the research is guided by the following objectives:

RQ1. To investigate the visual and structural characteristics of the Rafflesia flower that hold potential for textile pattern development.

RQ2. To apply photography and QCPA as a combined analytical method for translating biological imagery into design elements.

RQ3 To develop textile patterns that are ecologically informed, culturally resonant and adaptable for contemporary practice.

By addressing these objectives, the study proposes a replicable visual analysis process that integrates local biodiversity into textile design innovation. It not only contributes to creative practice but also advances the goals of Sustainable Development Goal 15: Life on Land by promoting design strategies rooted in environmental stewardship and cultural identity. Furthermore, this research extends the author's earlier work on photography's influence in designer cognition (Nik Aziz, 2021), demonstrating how structured photographic analysis can bridge ecological observation and design ideation, enriching both educational and professional practice in textile design.

FOUNDATIONS OF BIOINSPIRED TEXTILE DESIGN

Biomimicry is an interdisciplinary approach that draws inspiration from nature's time-tested forms, systems and processes to solve human challenges through sustainable innovation. Within textile design, biomimicry has gained prominence as a strategy for integrating ecological intelligence and visual aesthetics. Natural elements such as animal skins, insect wings and plant structures offer functional and visual characteristics that can be translated into textile materials and surface patterns.

Cabral et al. (2024) emphasise the capacity of natural patterns and pigments, such as those found in leaves and flowers, to be translated into textile design through colour reproduction technologies. Their research demonstrates how accurate digital representation of plant hues can enhance sustainable textile development and colour formulation. Complementing this, Subash and Perumalsamy (2023) highlight the potential of biomimetic structures to improve textile performance, including self-cleaning surfaces and increased durability by mimicking properties like lotus-leaf hydrophobicity or spider silk strength.

Kapsali et al. (2024) further explore biomimicry from a commercial lens, focusing on how biologically inspired textiles influence consumer perception. Their work supports the idea that market demand is increasingly aligned with sustainability values, where eco-conscious design decisions carry symbolic and functional value. Garg (2024) expands this discussion by calling for a deeper understanding of the practical integration of biomimicry in the textile industry, particularly in terms of scalability and manufacturability.

However, challenges remain in translating such inspirations into scalable, commercially viable designs. Garg (2024) calls for deeper exploration into the real-world applications of biomimicry in the textile industry. Meanwhile, Schröpfer (2012) emphasises that integrating ecological principles and natural systems into design enhances environmental awareness and aesthetic value, positioning bio-inspired architecture and patterning as powerful tools for sustainable and ethical design.

communication. In her seminal work, Benyus (1997) argues that biomimicry can offer sustainable solutions by imitating nature's time-tested strategies. Das and Martinez (2018) further elaborate on how biological principles can inspire the creation of innovative materials, drawing from natural models such as spider silk and gecko adhesion.

While these studies advance the theoretical and technical foundations of biomimicry in design, there remains a gap in understanding how visual data, particularly photographic imagery, serves as a mediating tool in the design process. In prior work by Nik Aziz (2021), photography was examined as a cognitive bridge that enhances designer empathy, perception and ideation by capturing product performance in real use contexts. Extending that insight into textile development, this study builds on the idea that photography does not merely record nature; it transforms it into a visual stimulus that informs creative decision-making, especially when analysed through structured approaches like Qualitative Colour Pattern Analysis (QCPA).

In summary, the reviewed literature demonstrates a growing convergence between biomimicry, material design, visual analysis and sustainability. However, few studies have examined the integrated role of photography, biological imagery and QCPA in driving eco-conscious textile pattern development. This study seeks to address that gap.

RESEARCH DESIGN AND VISUAL INQUIRY APPROACH

Case Study: The Royal Belum Rainforest's Rafflesia as a Source of Inspiration for Biomimicry

This study adopts a visual case study approach centred on the Rafflesia flower, one of the most biologically unique and culturally significant parasitic plants native to Southeast Asia. The research was conducted at the Royal Belum Rainforest in Gerik, Perak, Malaysia, over an extended fieldwork period during the data collection phase (see Figure 1 for map location). This protected rainforest area, known for its rich biodiversity, provided the ideal natural setting for investigating biomimicry through direct visual engagement with native flora.



Figure 1. The Location of Royal Belum Rainforest, Gerik, Perak, Malaysia.

Source: <https://www.google.com/earth/>, 2025

The Royal Belum Rainforest is located at approximately 5°N latitude and 101°E longitude. It is designated under the Perak State Park Corporation Enactment 2001 and comprises two ecological zones:

the Upper Belum, covering 117,500 hectares near the Malaysia–Thailand border and the Lower Belum, spanning approximately 300,000 hectares. These zones are home to various rare species, including *Rafflesia* spp., making the site both ecologically critical and visually significant for design-led inquiry.

The *Rafflesia* flower was selected as the subject of this case study due to its distinctive morphology, bold colouration and symbolic resonance. Its radial petal structure, interlocking surface patterns and rich warm tones offer extensive potential for design interpretation. As a parasitic plant that lacks leaves and stems, *Rafflesia* challenges conventional plant forms and presents a striking visual reference for pattern development in textiles. Importantly, *Rafflesia* is not only a botanical curiosity but also a cultural icon and an emblem of Malaysia's natural heritage. Its rarity underscores the urgency of conservation, while its visual identity offers a locally grounded narrative for sustainable design. By incorporating *Rafflesia* into textile innovation, this study seeks to highlight the value of local biodiversity as both an ecological asset and a cultural resource, reinforcing the role of design in supporting environmental awareness and national identity.

Photography was employed as the primary tool to capture the flower's intricate details in situ, supporting both artistic interpretation and structured analysis. A total of 150 high-resolution photographs were captured during fieldwork under varying lighting and compositional conditions to ensure a comprehensive visual dataset. These images were analysed using the Qualitative Colour Pattern Analysis (QCPA) framework to systematically identify dominant colour segments, tonal contrasts and structural motifs. The analysed data were then processed through a staged workflow. First, key visual elements extracted through QCPA were translated into annotated observations. Next, these elements informed hand sketches, allowing for the abstraction and stylisation of natural forms. The sketches were refined into motifs that preserved the essence of the *Rafflesia*'s visual identity while exploring new design possibilities. Finally, the motifs were developed into repeatable textile patterns ready for prototyping. This sequential approach ensured that each step built upon the previous one, maintaining both analytical rigour and creative freedom throughout the design process.

Qualitative Colour Pattern Analysis (QCPA) Procedures

To translate natural visual data into textile design, this study employed Qualitative Colour Pattern Analysis (QCPA), a framework adapted from ecological and visual research to analyse colour patterns through observational and artistic interpretation. Unlike quantitative colour science, QCPA emphasises subjective engagement with colour, shape, texture and pattern relationships, making it suitable for use in art, design and aesthetic research contexts (Kamaruddin et al., 2022).

QCPA in this study served as a methodological bridge between photographic imagery and design ideation, facilitating structured visual inquiry grounded in real-world biological references. The analysis involved a series of iterative stages, each supporting the progressive development of design elements from *Rafflesia* flower observations.

In the context of this study, the QCPA framework was applied directly to the photographic dataset of 150 high-resolution *Rafflesia* images. Each photograph was examined using the observation, description, interpretation, analysis and documentation stages outlined in Table 1. This systematic process identified key visual characteristics, including dominant warm-toned colour groupings, radial petal structures and interlocking surface patterns, which were extracted as design components. These components were progressively translated into hand sketches, stylised motifs and repeatable textile patterns, forming a coherent pathway from ecological observation to creative materialisation.

Table 1 summarises these stages as applied in this study's design workflow. The use of QCPA allowed for a dynamic interplay between subjective perception and methodical analysis, grounding the final textile outcomes in both natural inspiration and critical reflection.

Table 1. Qualitative Colour Pattern Analysis (QCPA) Various Stages

No	Stage	Descriptions
1	Observation	The colour pattern is visually observed and described in detail, including the colours used, their arrangement and any other visual elements. <i>(lines, shapes and textures)</i>
2	Description	The colours in the pattern are described using qualitative terms. <i>(Warm or cool colour)</i>
3	Interpretation	The colour pattern is interpreted based on its emotional, aesthetic and symbolic associations. This may involve considering cultural, historical and psychological factors that influence the perception of colours and their meanings.
4	Analysis	The observations, descriptions and interpretations are analysed to identify patterns, trends and relationships between colours and their meanings.
5	Documentation	The findings of the QCPA are documented in a written or visual form to communicate the results of the analysis.

Colour Pattern Analysis Process

Building upon the QCPA stages outlined in Table 1, this study operationalised the framework through three main practical phases: Observation, Description and Interpretation & Analysis. Each phase was directly informed by the photographic dataset gathered during fieldwork and refined through studio-based reflection. This combined use of photography, hand drawings and digital segmentation ensured that the resulting textile patterns remained rooted in authentic natural references while allowing room for creative abstraction and translation into commercially adaptable designs.

Observation Stage

The visual study began with close observation of the *Rafflesia* flower's form, colour and texture using high-resolution photographs taken on site. This stage focused on the spatial arrangement of colour blocks, petal structure, line rhythm and surface details such as papillae and mottled patterns, aligning with the QCPA-guided observation phase. Figure 2 illustrates the process of line drawing, conducted using graphite, pencil and paper, to isolate the *Rafflesia*'s prominent structural lines and contours. These sketches translated the flower's natural complexity into manageable visual information and served as a foundation for stylisation and motif development in subsequent design stages.

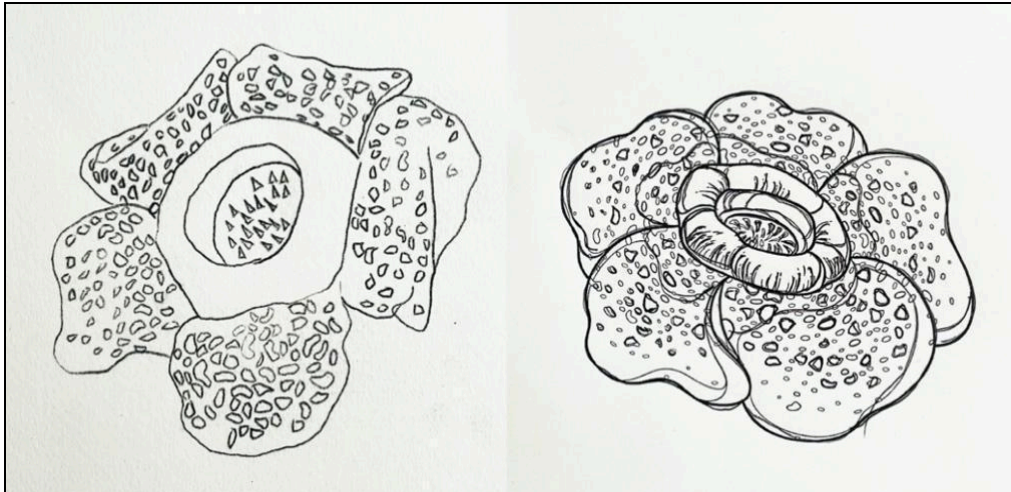


Figure 2. Image Observation with Line Drawing using Graphite, Pencil and Paper
(Source: Khairul Zikri, 2023)

The flower's shape and tactile surface were further analysed to understand how they contribute to its visual identity. Building on the initial sketches, this stage involved digital segmentation of high-resolution photographs using photo editing software (Adobe Creative Cloud). Figure 3 shows how this process highlighted distinct zones of colour and texture, enabling clearer identification of dominant patterns and structural contrasts. This analysis demonstrated how Rafflesia's irregular organic forms and contrasting surfaces contribute both to its striking visual impact and to its potential as a source of biomimetic design inspiration.

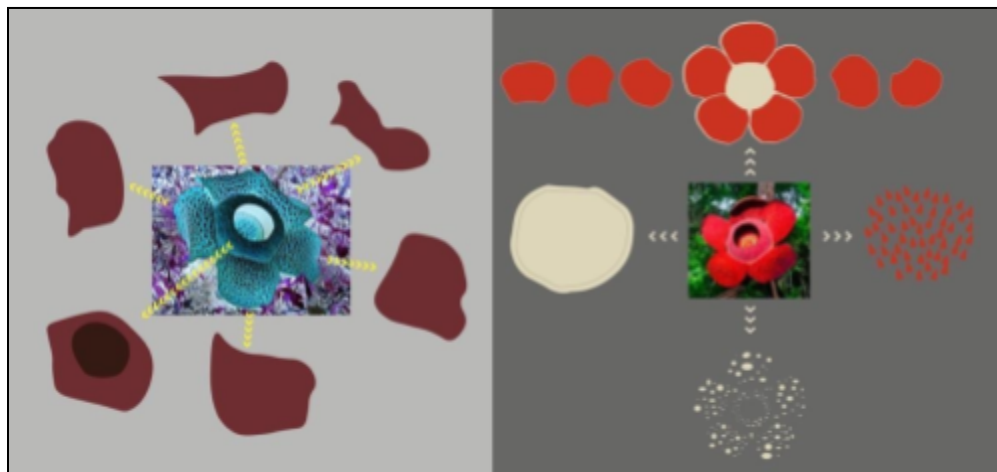


Figure 3. Image Segmentation for Shape and Texture Observation using Photo Editing Software (Adobe Creative Cloud)
(Source: Nik Nor Azidah, 2023)

Description Stage

At this stage, qualitative descriptors were assigned to the Rafflesia's colour palette, translating analytical findings into design language. Building on the segmented imagery, the dominant hues ranged from deep maroons to reddish browns and dark purples and were described using terms such as “earthy,”

“warm,” “intense,” and “organic.” Field observations were reinforced through watercolour studies (Figure 4), which allowed the researcher to approximate natural pigment tones manually and test their visual behaviour on a physical medium. These studies bridged ecological accuracy with artistic intuition and prepared the colour information for integration into stylised motifs and final textile patterns.



Figure 4. Field Observation using Watercolours to Mimic Natural Colours
(Source: Khairul Zikri, 2023)

To explore colour distribution within the flower’s structure, subjective image segmentation was performed using Patternize (Van Belleghem et al., 2018). This method allowed the study to map out primary and secondary colour zones, revealing the frequency, density and boundaries of visual elements across the flower’s surface (Figure 5).

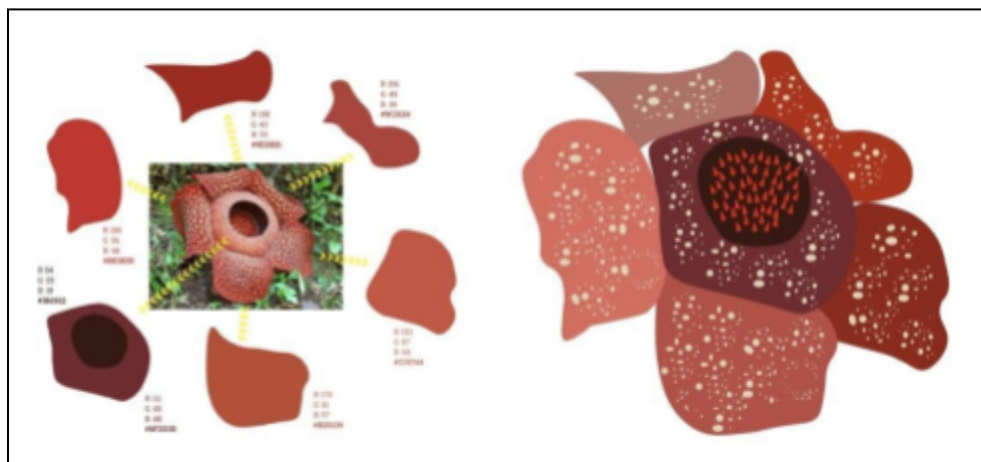
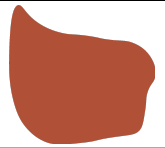
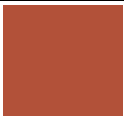


Figure 5. Colour Elements Image Segmentation within Rafflesia's Shape and Patterns
(Source: Nik Nor Azidah, 2023)

By applying colour theory principles to the study of Rafflesia flower colour patterns, this study can gain a better knowledge of the visual qualities, potential uses and design ideas that can be derived from

these natural colour patterns. This knowledge can be used to generate new and sustainable design solutions inspired by Rafflesia flowers and their colour palettes (Table 2).

Table 2. Extracted Colour Palette of Rafflesia: Hex Codes, RGB Values and Shape Mapping using Hex Color Codes (color-hex.org, n.d)

No	Segmented Shape	Hex Code & RGB Values	Colour Swatch
1		<i>#9e2b21</i> hex colour red value is 158, green value is 43 and the blue value of its RGB is 33.	
2		<i>#9c3124</i> hex colour red value is 156, green value is 49 and the blue value of its RGB is 36.	
3		<i>#c15744</i> hex colour red value is 193, green value is 87 and the blue value of its RGB is 68.	
4		<i>#b25139</i> hex colour red value is 178, green value is 81 and the blue value of its RGB is 57.	
5		<i>#361912</i> hex colour red value is 54, green value is 25 and the blue value of its RGB is 18.	
6		<i>#6f2d30</i> hex colour red value is 111, green value is 45 and the blue value of its RGB is 48.	
7		<i>#be3830</i> hex colour red value is 190, green value is 56 and the blue value of its RGB is 48.	

Interpretation and Analysis Stage

The final stage involved interpreting the meaning and visual impact of Rafflesia's colour and form in relation to design. Based on the colour palette derived in Table 2, the warm colour family, particularly shades of red, burgundy and brown, was found to evoke feelings of heat, energy and boldness (Figure 6: Warm/Cool Colour Wheel). These associations were particularly relevant in the context of mimicking Rafflesia's thermogenic function, where heat and scent are used to attract pollinators.

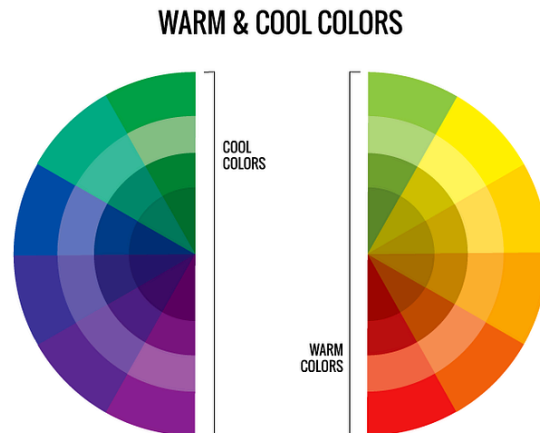


Figure 6. Colour Wheel for Warm and Cool Colours

(Source:

<https://medium.com/designare/understanding-colour-theory-a-beginners-guide-to-colour-theory-and-its-importance-e340849ad3f6>, 2021)

The patterns' symbolic associations were also considered. The radial symmetry and bold shapes of the petals suggested strength, balance and vitality. These interpretations were translated into a range of design responses, from abstract motifs to literal floral representations, later stylised for textile application. Figure 7 showcases one such outcome. It presents a colour palette inspired by Rafflesia's patterning, translated into stylised elements that maintain the spirit of the natural reference while allowing for visual innovation.

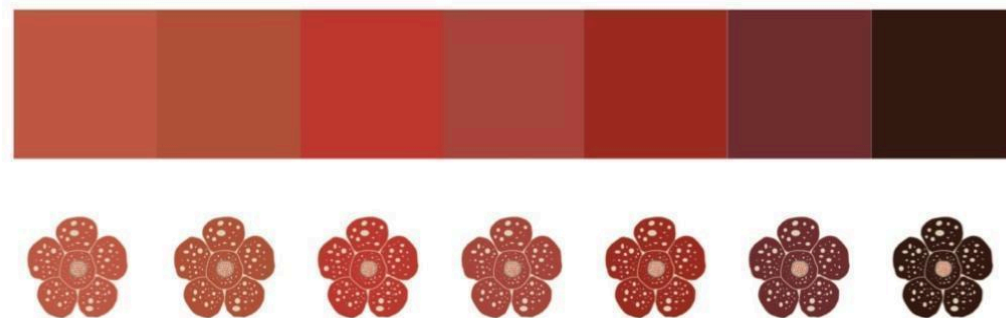


Figure 7. The Outcome of Warm Colour Palettes Inspired by Rafflesia Flowers and Their Patterns

(Source: Siti Nor Diana & Nik Nor Azidah, 2023)

RESULTS

Identification of Colour Patterns and Visual Properties

The application of Qualitative Colour Pattern Analysis (QCPA) revealed a dominant presence of warm, saturated hues across the surface of the Rafflesia flower. The colours ranged from deep maroon

and reddish-brown to dark purples and black tones. As identified through segmented image analysis (see Table 1), the extracted colour palette featured consistent warm tones associated with vibrancy, intensity and natural richness. These hues were mapped across various segments of the petal, papillae and inner structures, each presenting distinct surface textures.

The flower's radial symmetry and pattern consistency provided a strong structural framework for design interpretation. The combination of organic shapes and concentrated colour intensity created a compelling visual language. This visual language was documented through a sequence of artistic studies that included line drawings, watercolour representations and digital stylisation.

Colour perception varied depending on light exposure and the angle of observation. In natural low-light forest environments, some areas of the flower appeared nearly black, whereas under direct light, saturated reddish tones with a tactile sheen became visible. This complexity added visual depth and textural richness, expanding the range of possibilities for design translation.

Design Translation and Pattern Development

Insights from the colour and shape analysis were translated into a series of textile pattern explorations. Two creative pathways emerged:

Abstract Stylisation: Organic forms were simplified into flowing shapes, overlaid using repeated motifs that retained the spirit of the Rafflesia without literal representation. This method used the core colour palette and radial balance as compositional principles.

Literal Botanical Motif: A more representational approach that illustrated the flower's full form, stages of blooming and overlapping layers. These were arranged as central elements in textile layouts, ideal for statement patterns or placement-based designs.

The pattern could be rendered in warm, earthy colours and incorporate the distinctive shape and texture of the flower. Before entering commercialisation, it progressed through five key processes (Figure 8), with the resulting stages and outcomes presented in Table 3. Table 3 illustrates how each step in the five-step design process contributes to the development of the final textile pattern.



Figure 8. Five-Step Design Process

Table 3. Summary of Subject Matter, Drawing, Stylisation, and Pattern Development Stages
 (Source: Siti Nor Diana & Nik Nor Azidah, 2023)

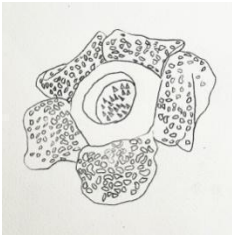
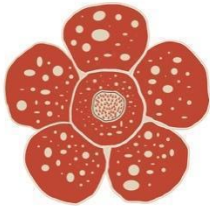
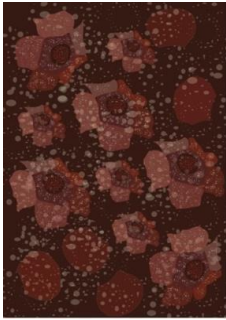
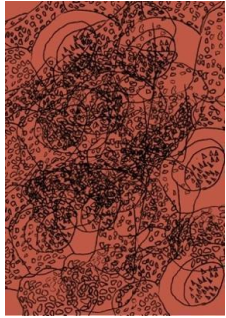
Items	Visual	Description
<i>Subject Matter</i>		<i>The chosen Subject Matter was discovered in the research area.</i>
<i>Drawing</i>		<i>Analytical drawing is a traditional technique of graphite, pencil-and-paper drawing used to analyse form, space, shape and line as design aspects from the subject matter and to explore the subject matter's characteristics.</i>
<i>Stylisation</i>		<i>Stylisation complements drawing by adding warmth, colour and depth to achieve the desired look or feel.</i>
<i>Design Pattern</i>		<i>Textile Design Pattern is the process of creating designs and patterns on fabric.</i>

Table 4. The Potential of Textile Design Pattern (Product)
(Source: Siti Nor Diana & Nik Nor Azidah, 2023)

Design No.	Pattern Visual	Conceptual Notes / Design Intent
1		Rafflesia's shape is disassembled into basic elements and used as the basis for a design. The unique shape of Rafflesia's leaves is used as a background. The warm and earthy colours of Rafflesia are used to create a rich and inviting colour scheme.
2		The stylisation of the petals and stamens of Rafflesia. The background and the main textile pattern design used the same colour scheme. Papillae are used as a scattered background.
3		The intricate and organic shapes of the Rafflesia's petals and stamens. The outline of the overlapping, unique and organic shape of Rafflesia provides a basis for creating bold and abstract patterns. Background based on the warm and earthy colour palette of Rafflesia.

4		Rafflesia-inspired pastel hue is used as a background. The application of pattern repetition. Outline of petals, stamens and papillae.
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CONCLUSION AND RECOMMENDATIONS

This study demonstrates the potential of biological imagery, particularly the Rafflesia flower, as a rich source of inspiration for sustainable textile design. By applying Qualitative Colour Pattern Analysis (QCPA) and using photography as a mediating visual tool, the research translated natural observations into meaningful design outcomes. The resulting patterns reflect a synergy between ecological richness and visual storytelling, enabling designers to engage with nature through form, colour and texture.

The extracted colour palette, dominated by warm, earthy hues, proved to be both aesthetically impactful and symbolically resonant. Through sketching, stylisation and digital rendering, these colours and organic structures informed the development of textile motifs that ranged from abstract to botanical. The five-step design process, which encompassed subject identification, drawing, stylisation, pattern design and product application, ensured that the creative outputs remained grounded in field-based observation and structured analysis.

Beyond their visual impact, the findings contribute to broader ecological and cultural discourse. They align with Sustainable Development Goal 15: Life on Land and promote biodiversity awareness through material and visual engagement. Moving forward, this approach could be extended to explore other biological subjects, including insects, marine ecosystems and forest-based textures, offering new directions for nature-driven design innovation. Collaborative efforts between designers, conservationists and local communities may further amplify the cultural relevance of bioinspired textiles. Integrating these methods into design education could foster greater environmental sensitivity and critical visual research skills among emerging creatives.

In conclusion, this study establishes a replicable framework for translating local biodiversity into sustainable textile design by combining photographic documentation, Qualitative Colour Pattern Analysis and structured creative development. It demonstrates how culturally significant flora, such as the Rafflesia flower, can inspire ecologically responsible patterns that carry both aesthetic and symbolic value, offering pathways for innovation in design practice, conservation awareness and environmental education.

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