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Biodesign: a means to preserving indigenous craft practices

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Abstract

Biodesign, an innovative multidisciplinary approach to design, addresses anthropocentric challenges by minimizing ecological footprints in product and system creation. It incorporates living organisms such as bacteria, fungi, plants and algae into products and manufacturing processes. This approach harnesses the organisms' potential, including their metabolic activities, growth, stimuli responses, reproductive capabilities, and relationships with other life forms, to create living-like design outcomes. Indigenous communities have a historical connection to living systems in agriculture, wine making and traditional crafts, offering valuable insights.

This paper presents a real-life case study of the Kotpad craft community in Odisha, India, highlighting their challenges. As indigenous communities like the *Mirigan* craftsmen face pressure to integrate into the mainstream economy, there is a risk of losing their connection with nature, traditional knowledge, and unique identity. The paper envisions the possibility of Biodesign applications in indigenous craft practices and explores hypothetical approaches to problem-solving by application of Synthetic Biology to indigenous crafts preservation. It critically analyzes the advantages, disadvantages, ethical considerations and socio-economic-cultural implications for the community.

Introduction

Indigenous knowledge as defined by UNEP (United Nations Environment Programme) and Mugabe (1998), encompasses the knowledge held by the indigenous people specific to their territorial place, marked by cultural distinctiveness and historical precedence in territorial occupancy compared to the most recently arrived community with its own distinct culture, subsequently becoming dominant." plays a crucial role in understanding various aspects of the world (Orozco & Poonamallee, 2014). This knowledge is characterized by oral traditions, hands-on experience, and a holistic view of the environment, recognizing the interconnectedness of all things through empirical observations and collective experience (Brodnig and Mayer-Schönberger, 2000, p. 5).

Indigenous Knowledge (IK) and traditional crafts are intrinsically linked, with both serving as vital elements of intangible cultural heritage (ICH). Traditional crafts embody and manifest indigenous knowledge through their development and preservation over generations within a community. They represent the shared experiences and wisdom of the people. The defining features of traditional crafts include collective ownership, anonymity and oral transmission. Moreover, these crafts often reflect syncretism by integrating elements from diverse cultural practices. Both IK and traditional crafts are grounded in accumulated, communal experience and are deeply intertwined with cultural practice and environmental insights (Ionică, 2022).

Traditional crafts often involve the creation of tools, materials, and sustenance, aligning with the holistic approach of IK that integrates cultural significance, environmental stewardship, and practical utility. By embodying the principles of indigenous Knowledge, traditional crafts highlight the relevance of these practices to the broader field of ICH, underscoring their importance to humanity's cultural and historical fabric (Brodnig and Mayer-Schönberger, 2000).

The integration of art, Science, and Design in Biodesign involves innovative applications of Biotechnology, Synthetic Biology, 3D Biofabrication and Biocomputation to achieve specific goals.

Biodesign encompasses a wide array of practices that integrate biological systems into design process, bridging traditional methods with innovative fields like Synthetic Biology. Unlike conventional design, which typically begins with abstract concepts, Biodesign often starts with existing biological components. This approach emphasizes direct manipulation, iterative refinement, and trial and error, demonstrating a profound understanding of the biological medium, much like craftwork. Rather than adhering to a single theoretical framework, Biodesign is characterized by its diverse methods and perspectives (Dade-Robertson & Zhang, 2024).

However, the foundational values and principles of Biodesign can be traced back to ancestral wisdom and practices that persist among indigenous communities worldwide. Unlike contemporary perspective that often view nature as a separate entity, indigenous communities have co-evolved with their environments, fostering a symbiotic relationship where each influence and shapes the other.

This interconnected worldview is mirrored in the sustainable practices of traditional crafts. Sustainability plays a crucial role in understanding how crafts can meet community needs through creative enterprises that blend traditional skills with contemporary artistic visions. (Wechakama, 2011). This approach also involves integrating heritagization with the innovative reinvention of traditions and crafts (Guan, Gao, and Zhang, 2019). Industrialization has threatened the survival of traditional crafts, often simplifying them where they do persist. However, providing structured support can foster the revival and creative development of these crafts, enhancing community incomes and instilling a greater sense of cultural pride (Goldsmith, 2013; Zbuchea 2022).

Integrating Biodesign with traditional crafts enables sustainable practices that honor ancestral wisdom while incorporating modern technology. This approach revitalizes traditional crafts and aligns with Biodesign's holistic principles, creating a future that respects both cultural heritage and technological progress. To explore and conserve these traditional Biodesign knowledge systems, I conducted a field studying Kotpad, located in the Koraput district of Odisha, India – a region renowned for its indigenous crafts, abundant mineral resources, agriculture, and diverse tribal populations. This study aims to illuminate Indigenous Biodesign practices in the region and how modern Biodesign can contribute to the advancement of Indigenous communities.

Kotpad craft cluster case study

Kotpad, a region home to the Mirigan community, is renowned for its exceptional expertise in textile dyeing, particularly using pigments from *Morinda citrifolia* roots skins, locally known as *Aul*. This community is part of the larger *Panika* group found in Chattisgarh and Madhya Pradesh. Although more than 100 members of the *Panika* tribe migrated to Kotpad, decades ago, where they continue to uphold their ancestral traditions.

The *Mirigan* weavers are renowned for their intricate craft, which combines traditional yarn preparation and dyeing techniques with a complex weaving method involving three shuttles on a pit loom. This artistry combined with supplementary extra weft technique produces striking patterns of red against white cotton fabric. Their unique craftsmanship has earned Kotpad's textiles a prestigious Geographical Indication registration from the Indian government. Historically, the textiles were primarily used within the community and by a few neighboring groups, serving as ceremonial attire for weddings and rituals.

However, this craft is facing complex and multifaceted challenges. The pressure of consumerism and assimilation into the mainstream economic system has led some weavers to shift towards chemical dyeing, often outsourcing production to weavers from different communities, endangering the future of the craft.

Ancestral Biodesign knowledge in Kotpad dyeing

The Kotpad textiles craft uses the bark and root skins of *Aul* trees abundant in the forests of Koraput for its distinctive dyes. This traditional process involves a meticulous preparation of yarns using a blend of cow dung, ash water and castor oil. This technique highlights a long-standing tradition of utilizing animal dung in textile pre-treatment and dyeing, illustrating its enduring role in sustainable and eco-friendly craftsmanship.

In Thailand, the Ban Don Samo Weaving Community in Si Songkhram District incorporates buffalo dung in its textile dyeing practices. This community's reliance on water buffalo underscores a symbiotic relationship with this vital agricultural resource, emphasizing the sustainable and eco-friendly aspects of using dung as a raw material for dyeing (Bureekhampun & Maneepun, 2021). Similarly, in Southeast Asia, goat dung has been used traditionally for dyeing fabrics. Boiled in water and applied to cloth, goat dung has a high potassium, nitrogen, and phosphorus content enhances color stability, while manual techniques such as pounding with stone pestles ensures color durability and resistance to washing to washing and fading (Bhattarai & Praditpornsilpa, 2018; Bureekhampun & Maneepun, 2021).

Animal husbandry not only supports rural economies but also contributes to environmental sustainability by functioning as a natural carbon sink. In Southeast Asia, this sector plays a crucial role in agriculture, providing essential products like meat, milk and eggs that are vital for nutrition (Subramaniyan et al., 2017).

Cow dung, an undigested residue of consumed food material byproduct of herbivores cattle, contains a mixture of feces and urine rich in lignin, cellulose, hemicelluloses and various minerals. Its microbial diversity contributes to its utility in textile processes (Gupta, Aneja, and Rana, 2016).

In rural India, where 63.6% of the population resided till 2023 (World Bank, 2024), cow dung is a valuable resource, repurposed for cooking fuel, construction material, mosquito repellent and cleaning agent, highlighting its socio-economic importance (Dhama et al., 2005).

The Kotpad yarn preparation involves coating and massaging the yarns with a mixture of ash water, castor oil and fresh cow dung.

The interaction between castor oil and alkaline ash water in this process resemble those of Turkey red Oil (TRO), a well-known anionic surfactant produced through the saponification of castor oil (Ogunniyi, 2006). TRO's effectiveness in removing non-cellulosic constituents from fibers makes it a useful additive in textile processing (Qiuyan Chen et al. 2020).

The ash water, derived from charred rice husk mixed with water and aged, in an earthen pot buried in the household backyard, facilitates a mild saponification reaction with castor oil, effectively cleansing the yarns and preparing them for dyeing.

The cow dung exemplifies the biodigestion process in the yarn preparation stage, facilitated by the gut bacteria and enzymes in cow dung. The interaction of the cotton yarns with cow dung partially breaks down the cellulose in fibers. This intricate process serves as an alternative to the use of mordants as well as scouring reagents, which are conventionally employed in the dyeing process offering enhanced fiber porosity, dye accessibility and minimizes wastage. The yarns are coated with cow dung they are dried under the sun. This daily application and drying continues over a month and then washed to reveal a yellow color.

Ruminococcus flavefaciens, Ruminococcus albus and *Fibrobacter succinogenes* are key cellulolytic bacteria in the rumen, each playing a significant role in cellulose degradation. *Ruminococcus flavefaciens* is typically gram-positive or Gram-variable and is known for producing a distinctive yellow pigment, especially when cultivated on cellulose (Hua, Hendriks, Xiong, and Pellikaan, 2022).

Yarn preparation is followed by a dyeing process where the treated yarns are soaked overnight in a mixture of castor oil, ash water powdered *Aul* tree skins, and tannin (such as *Terminalia chebula)*. Then yarns are boiled in large iron vats. This dyeing process is repeated thrice to achieve the desired maroon hue. Village women play a vital role in this process. This unique preparation procedure is carried out with a sense of celebration, often accompanied by singing and rhythmic dancing.

Cow dung's role extends beyond scouring to act as a mordant due to its mineral content, including copper and zinc, which bind dye molecules. Studies have shown that cow dung, alongside ash water, can serve as effective mordants in dyeing processes. For instance, Saravanan and Chandramohan (2011) utilized cow dung and *myrobolan* as mordants to dye silk with natural dyes from *Ficus religiosa* L., achieving vibrant colors with satisfactory fastness. A study by (Janani & Winifred, 2013) assessed dye fastness on silk fabrics from coffee and mulberry leaves using ash water and cow dung as mordants. Ash water performed well in wash and heat fastness, but cow dung performed good in lightfastness in the resulting dyed fabrics. Similar practices, such as Turkey dyeing in Scotland, also illustrate the global relevance of utilizing excreta in textile processes (Shahid, 2019).

This traditional method of using animal dung in textile preparation and dyeing reflects a deep connection between indigenous knowledge, environmental sustainability and craftsmanship. It also highlights how microorganisms influence broader socio-cultural and economic dynamics, shaping both crafts and traditions.

Craft evolution and challenges

Over the course of 80 years, the Kotpad craft has undergone significant transformations that have reshaped its contemporary identity. The evolving role of the craft is to continually support the community, serving by documenting traditions, providing artistic expression, and sustaining livelihoods. Its ability to adapt and respond to the evolving needs of its artisans is key to its continued relevance, as demonstrated by the Kotpad's example.

This evolution is clearly demonstrated by the shift in the color of Kotpad dye, which has been influenced by changes in materials and techniques. Historically, older sarees featured a mauve hue, whereas contemporary ones exhibit a vibrant red. The transition is due to the substitution of traditional terracotta vessels with iron ones in the dyeing process, which introduces ferrous elements and produces the distinct rustic red. The change reflects greater access to markets that provide materials with enhanced durability allowing for improvements in the craft, contributing to its evolving characteristics (Figure 1).

Substantial changes have occurred in the layout, composition, and *materials* of woven textiles to align with current market demands. Nevertheless, the key issue is determining how much a craft can evolve without losing its fundamental values. The challenges faced by the craft are significant and complex, requiring ongoing efforts to address them effectively.

1. The sourcing of root and bark is intricate. Extracted by economically disadvantaged forest dwelling communities rather than weavers, this practice often operates in a legal gray area due to forest department regulations, contributing to the illegal trade of these valuable materials. This not only threatens the ecosystem but also makes the trees susceptible to pests.
2. The labor-intensive yarn preparation process with a month-long sun drying phase is limited to sun-drenched months. These constraints impact production quantities and increase costs.
3. The demanding dyeing process, requiring three times the weight of the fabric to dye stuff ratio, intensifying the strain on the extraction process. Additional costs are incurred from purchasing cow dung, firewood, and castor oil from the market creating a difficult, time-consuming condition as an obstacle to the craft's sustainability.
4. Traditionally, weaving has been a supplementary income source and a means for artistic expression for the community, with agriculture as their primary occupation.

However, the craft's viability has been threatened as the tribal economy has shifted towards capitalism. Weavers now face the difficult choice between prioritizing agriculture, using chemical dyes, or seeing younger generations abandon weaving to adapt to new economic conditions. These challenges highlight the complex interplay between the craft, community, livelihoods, and evolving economic forces.

Future of Kotpad craft

The current landscape presents a multifaceted challenge encompassing economic, environmental, political, and social dimensions. Historically, the intrinsic value of the Kotpad craft was interwoven with the daily existence of the *Mirigan* community, serving both as a means of survival and a form of cultural expression. To restore the craft's significance, establishment of a sustainable system involving technological advancement could be a promising direction.

Craftsmanship in Bio Design includes the role of tacit knowledge-intuitive, experiential understanding developed through direct interaction with biological media. This knowledge is integral to both experimental science and Bio Design, demonstrating a blend of skilled practice and theoretical planning while Synthetic Biology, as a subset of Bio Design, distinguished by its structured, engineering-inspired approach to biological design (Dade-Robertson & Zhang, 2024).

Natural dyes have been used since early human civilizations since 15,000 BC, with evidence from the Altamira cave paintings, and ancient textiles from Egypt and India (Bechtold et al., 2003). Despite their historical significance, natural dyes lost favor in the late 19^{th} and early 20^{th} centuries with the advent of synthetic dyes, which were cheaper, more varied, and reproducible. This shift led to the collapse of the plant-based dye industry and the rise of synthetic dyes, which caused significant environmental harm through toxic waste discharge into freshwater sources, contributing to ecological issues like algal blooms and greenhouse gas emissions (Agarwal et al., 2023). The dominance of synthetic dyes also disrupted the development of natural dyeing techniques to meet modern demands (Bechtold et al., 2003).

Bacterial pigments are currently a promising sustainable alternative to synthetic dyes. These microbial dyes, which are byproducts of bacteria, represent a novel and less explored source of natural dyes. Though often referred to as 'pigments' due to their water-insoluble nature and common use in powder form or suspensions, bacterial pigments function more like dyes in textile science because they can chemically bond with textile fibers. Additionally, they are nontoxic to human skin, economically viable to produce and scale, and offer benefits such as UV protection and defense against competing species. Advances in recombinant DNA technology have further enhanced the efficient biosynthesis of these pigments, reducing the reliance on large-scale plant cultivation (Kramar and Kostic, 2022).

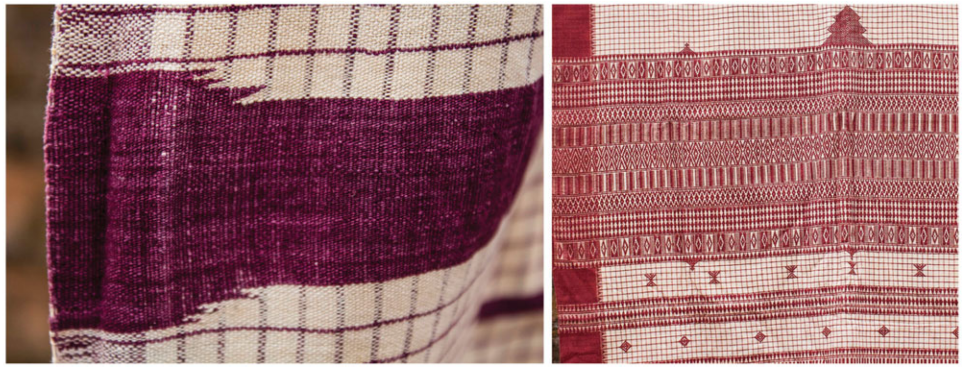

Figure 1. Pic 1 (Left): 80-year-old saree with mauve hue achieved using earthen pots for boiling the yarns with Aul dye during the dyeing process. Pic 2 (Right): Contemporary Kotpad sarees with yarns boiled with *Aul* dye in iron vats adding rustic red to the achieved color.

Synthetic Biology is emerging as a transformative field in material science and biotechnology that enables the design and construction of new biological parts, devices and systems that mimic the desirable properties of natural materials. It applies engineering principles to biological systems where DNA serves as the foundational code for the biological components, which are then assembled into more complex systems. This approach emphasizes standardization, modularity, and abstraction, facilitating rational design for industrial applications and offering potential solutions for environmental and industrial challenges. Soon, synthetic biology is expected to reshape the products we use, manufacturing processes and consumption patterns (Garner, 2021; Burgos-Morales et al., 2021).

The textile industry offers a clear example of synthetic biology's potential, particularly in developing sustainable fashion alternatives. Traditional clothing manufacturing contributes to pollution through microplastics, but companies like Bolt Threads have addressed this issue by engineering yeast to produce spider silk. This silk can be purified and spun into biodegradable fibers. In 2019, a collaboration between Bolt Threads, Stella McCartney and Adidas resulted in the showcase of a tennis dress made from a blend of microsilk and cellulose fibers, highlighting the innovative possibilities that synthetic biology brings to fashion (Garner, 2021).

A prospective avenue for keeping the red *Aul* dye still alive in the Kotpad community involves the utilization of synthetic biology to produce red pigments.

Anthraquinones are a diverse group of natural compounds known for their vivid colors and industrial applications as synthetic dyes. Synthesized as secondary metabolites by various organisms, including bacteria, fungi and plants, they possess a range of biological activities, such as anticancer and antimicrobial effects. Their synthesis occurs through the polyketide pathway in bacteria, fungi, and plants, and the shikimate pathway exclusively in plants (Mund & Čellárová, 2023).

These compounds are found across numerous plant families, such as Leguminosae and Rubiaceae, and include about 700 known anthraquinones (Diaz-Muñoz et al., 2018).

Morindone, a natural anthraquinone compound, historically, it was used as a red dye in textiles, primarily extracted from the root bark of *Morinda citrifolia, Aul* root skins used by the Kotpad community. It possesses approximately 0.5% morindone along with alizarin, damnacanthal, rubiadin, soranjidiol and lucidin. This natural dye was valued for its color and durability in fabric dyeing practices. Discovered by Thomas Anderson in 1849, morindin is an orange-yellow crystalline substance from *Morinda citrifolia* root, which, when distilled, yields morindone – a reddish crystalline compound soluble in alcohol or ether. In the Madras Presidency, the *Al* roots or *Aul*, Anderson found that while morindrin was ineffective for traditional dyeing methods, it could produce a permanent but dull red color when used with Turkey red mordant (Khai Ly Do and Zhao, 2022; Stenhouse, 1864).

For generations, the roots and stems of noni plant (*Morinda citrifolia*) has been a vital source of fabric dye in traditional Indonesian textiles. The tropical climate of Indonesia, where the noni plant thrives, supports its widespread availability and promotes environmental sustainability. The plant's stems and roots of noni consist of secondary metabolites such as anthraquinones, flavonoids, and tannins, which not only produce vibrant colors but also additionally offer antibacterial and antiviral benefits (Rahman, Muktiningsih, Andika, Kartini, and Slamet, 2018).

LabCom's 'AnthraLab' is a collaborative initiative involving UMR 7365 CNRS – Université de Lorraine, IMoPA, and Abolis Biotechnologies, focused on producing anthraquinone dyes from microbial sources. By integrating expertise in polyketide biosynthesis with synthetic biology and metabolic engineering in E. coli and yeast, the project aims to develop biodegradable, low-toxicity anthraquinone dyes. The objective is to provide a sustainable, eco-friendly alternative to synthetic colorants, taking advantage of the stability and effectiveness of natural anthraquinones and supporting the goals of Europe's Green Deal (Weissman, 2023).

The genesis of this idea originated from the desire to establish an endless, sustainable supply of *Aul* dyes while ensuring ethical extraction practices with controlled parameters. Among various avenues, the exploration of microbial platforms and metabolic engineering emerged as the most promising direction to create alternative natural sources of targeted specific anthraquinone compounds, replicating *Aul* dye sourced from *Morinda citrifolia* trees. However, this transition requires a comprehensive investigation into viability, scalability, and economic feasibility for implementation in traditional craft practices of Kotpad. Moreover, this shift prompts pertinent questions about the 'Identity of the dye'. While microbial production can replicate Aul dye's properties, it differs from traditional tree-based extraction, which involves a collaborative system with Kotpad weavers and neighboring communities. Although the microbial dye may share similar traits, it might not capture the essence of the tree-extracted *Aul* dye. Investigating the potential impact on the craft, including its perception among craftsmen, patrons, tools and techniques, is essential to ensure that this innovation integrates seamlessly while respecting craft's heritage and community sentiments.

Application of synthetic biology in vanilla production is one major example of how synthetic biology affects the community growing the crop for generations. In Madagascar, a country known for its vanilla, nearly 26 million people endure significant poverty despite its rich heritage. The high-value vanilla crop often relies on child labor and exploitation due to its labor-intensive nature and market volatility, while unsustainable farming practices led to environmental degradation and food insecurity (Herrera, 2021). Globally, less than 1% of vanilla flavor comes from real vanilla beans, with most vanillin produced synthetically (Bomgardner, 2016). As the demand for bio-vanillin surpasses plant-based supply, microbial genetic and metabolic engineering of renewable biomass offers a sustainable alternative for producing bio-vanillin (Xu et al., 2024). Evolva has developed a yeast strain that produces vanillin glucoside from glucose, providing a synthetic option to petrochemical vanillin (Bomgardner, 2016). However, this raises socio-economic concerns for traditional vanilla producers and issues related to traditional knowledge and benefit-sharing (Erosion, Technology and Concentration (ETC) Group, 2013; Meienberg et al., 2015). Additionally, the impact of feedstocks, potential containment risks, and regulatory aspects for product labeling will influence the adoption and market dynamics of synthetic vanillin (Redford et al., 2019).

In the two contexts, synthetic biology highlights its dual impact. In the anthraquinone dye project, it enables the creation of sustainable, biodegradable dyes, aligning with environmental goals and reducing reliance on toxic chemicals on an industrial scale. Conversely, the development of synthetic vanillin presents both opportunities and challenges: it offers a sustainable alternative to vanilla but poses socio-economic risks to traditional producers. This contrast highlights that while synthetic biology can advance sustainability and innovation, it must address socio-economic impacts on indigenous communities and ensure fair practices and benefit-sharing to mitigate potential disadvantages (Figure 2).

Ethical considerations of Biodesign application

Synthetic biology offers transformative potential in creating new life forms and addressing complex problems, but it also presents significant ethical challenges. On the advantage side, it allows for precise engineering of biological systems, potentially leading to breakthroughs in various fields. However, ethical concerns include the risks associated with unintended consequences of synthetic organisms, such as ecological disruption or biosecurity threats. The responsible design and use of synthetic biology requires rigorous safety measures, transparency, and accountability to prevent misuse and manage the potential impacts on society and the environment (Garner, 2021). The deployment of synthetic biology tools raises socio-economic and regulatory uncertainties that impact affected communities. As synthetic biology progresses, this could negatively impact local communities and their livelihoods by rising demand for its feedstock may trigger market fluctuations, including food price instability. This might potentially threaten the cultural heritage and conservation efforts of Indigenous peoples as market disruptions can lead to shifts in land use. To mitigate these impacts and address the socio-economic challenges posed by synthetic biology, it is crucial to carefully consider regulatory frameworks and the interests of affected communities (Macfarlane et al. 2022; George et al., 2019; Kofler et al., 2018).

Biopiracy and intellectual property concerns

In the application of synthetic biology and Biodesign within the Kotpad community, a critical consideration is the risk of Biopiracy. This scenario involves external entities exploiting indigenous knowledge and resources without due compensation or informed consent, posing a significant threat to the Kotpad community's control over their traditional knowledge and resources when biotechnological advancements are commercialized (Rose, 2021).

The Kotpad community's current educational, infrastructural, and economic circumstances often necessitate external intervention. However, any such involvement must be guided by a well-structured legal framework and ethical principles to mitigate the risk of Biopiracy and commercial exploitation. Consequences that are divorced from a sense of respect and benefit-sharing can raise ethical questions (Orozco & Poonamallee, 2014).

Lack of attribution

Another issue where third parties fail to acknowledge the source of inspiration or the role of the Kotpad community when utilizing their cultural elements. This omission is a form of appropriation that overlooks the origins and cultural significance of the knowledge and practices involved (Davis, 1994).

Out-of-context use

Using the pigments in contexts unrelated to their original cultural or ceremonial significance can be considered inappropriate. This practice disconnects the pigments from their cultural roots, potentially leading to misunderstandings or misinterpretations.

Environmental concerns

A paramount concern revolves around the potential release of genetically modified organisms into the environment, carrying the risk of ecological repercussions such as containment breach by novel organisms, genetic transfer and hybridization with local environmental species (Redford et al., 2014). The gravity of the situation is compounded by the potential compromise of community safety in the event of human error or infrastructure breakdown, impacting the overall well-being of the community. It is equally crucial to acknowledge and address the apprehensions of indigenous communities regarding the safety and sustainability of synthetic biology applications. Achieving a balance between innovation and environmental protection within the context of indigenous settings necessitates a comprehensive approach that prioritizes ecological integrity, community well-being and the preservation of traditional knowledge emphasizing respect, collaboration and fair recognition of the community's cultural heritage.

Loss of traditional craft skills

One significant concern is the potential erosion of traditional craftsmanship skills which have been meticulously passed down through generations. The introduction of synthetic biology-based alternatives carries ramifications beyond the craft itself-it alters the intricate human dimension, characterized by the physical, socio-cultural interactions between artisans and their craft communities. It is crucial to recognize that the allure, prominence and enduring value of Kotpad craft are intrinsically tied to its unique techniques, shaped by artisans' direct, physical engagement with the craft over extended periods. This hands-on approach profoundly influences people's perception of craft. Moreover, the craft process weaves the community together, fostering a sense of unity among individuals, families, and women who collaborate as a cohesive entity. The introduction of unfamiliar techniques could potentially disrupt the

Figure 2. Clockwise from left, Pic 1: Application of cow dung, castor oil, and ash water as part of the yarn preparation process. Pic 2: Hanging the yarns coated with cow dung for the biodigestion process. Pic 3: The change in colors of the yarns after one month of repeating the same process and drying them under the sun. Pic 4: The root skins of Morinda citrifolia trees (Aul) used for dyeing. Pic 5: Soaking yarns in Aul dye, castor oil, and ash water, and tanning for one day under the sun before boiling the yarns. Pic 6: Boiling the yarns in big iron vats by the weaver. Pic 7: Drying the dyed yarns under the sun. Pic 8:The usage of Aul-dyed yarns in a traditional Kotpad saree woven by Kapileshwar Mohanto.

social fabric of the community, affecting the intricate web of relationships that underpin the craft's cultural and communal significance.

In summation, the proposed solutions offer a holistic approach to tackle a multitude of interconnected challenges while ushering in a new era of sustainability, innovation and self-reliance for the craft of Kotpad.

Advantages of Biodesign application in Kotpad craft practices

The proposed hypothetical solutions address a complex web of interconnected issues, including intricate supply chain challenges and labor-intensive production processes. The application of Biodesign offers numerous advantages that can potentially revolutionize the status quo.

Reduced dependency on external raw materials

Given the prevailing challenges related to *Aul* dye extraction and the need for firewood, this advantage holds paramount importance in ensuring the sustainability of the craft. It not only streamlines the supply chain but also contributes to the craft's resilience.

Minimized impact on trees and immediate environment

The process does not render the trees vulnerable, aligning with the broader goal of environmental preservation.

Unlimited supply of Dyestuff

This transformative aspect opens doors to unprecedented opportunities for innovation, scalability, and the enduring sustainability of the craft by ensuring a consistent and abundant source of crucial materials.

Establishment of self-sustaining systems

They not only address immediate challenges but also create a framework for long-term viability of the craft, fostering its resilience and adaptability in rapidly changing landscapes.

In summation, the proposed solutions offer a holistic approach to tackle a multitude of interconnected challenges while ushering in a new era of sustainability, innovation, and self-reliance for the craft of Kotpad.

Conclusion and perspective

In this article, I conducted a critical analysis of the potential application of Biodesign in addressing the challenges faced by indigenous communities. I introduced the case study of the Kotpad craft community, with a specific focus on craft preservation. In this paper, I explored ancient Biodesign solutions grounded in Biodesign principles, examined their potential advantages and disadvantages, and explored the subsequent ethical considerations that should guide the future of the craft. Indigenous knowledge, which arises from deep co-creation with the natural environment, is reflected in unique cultural crafts, both tangibly and philosophically. Biodesign resonates with this concept of co-creation but pushes it further by integrating natural and artificial elements with the application of Synthetic biology in craft preservation. The shift from merely maintaining traditional practice to actively controlling biological phenomena, by the Indigenous communities, which revere nature as a divine creator to preserve these crafts in the face of evolving social and technological landscapes represents a momentous change. For communities like the Kotpad craft cluster, this transition involves profound psychological and cultural shift. It affects not only their lifestyle but also every facet of their environment, potentially altering their economy and interactions with other communities, with all the associated risks of unintended consequences.

The craft practices of Kotpad weavers are crucial for their cultural heritage and identity, making their preservation essential. Integrating Biodesign to safeguard this knowledge requires an integrated approach and robust legal and infrastructural frameworks:

Infrastructure: Effective technological and educational infrastructural development supported by local authorities for research, development, and containment of novel organisms is crucial. Education empowers the community, that offers them agency over knowledge and resources.

Inclusive Dialog: Successful Biodesign implementation in this context requires deep understanding and consent from the Community, robust legal frameworks must be established to protect intellectual property and ensure accountability, carefully managing power dynamics between the community and external parties to prevent exploitation. Alongside frameworks that respect the diverse perspectives of both the indigenous community and technology developers, ensuring that the community maintains an agency and that their traditional knowledge is honored through Co-design and participatory governance of the craft.

Philosophical Reconciliation: addressing philosophical differences between indigenous and scientific perspectives on environmental and biological manipulation is vital. Developing new knowledge frameworks that harmonize these viewpoints will be key to aligning goals and creating effective guidelines.

Anticipation of Consequences: anticipating and managing potential unintended consequences-such as social, economic, environmental and cultural impacts – is critical. A proactive approach to these challenges will help ensure that the integration of Biodesign benefits the community while preserving its cultural heritage.

In summary, integrating Biodesign with indigenous craft practices like those of the Kotpad community requires thoughtful approach that balances traditional knowledge with technological advancements. By addressing power dynamics, respecting cultural philosophies, and anticipating potential impacts, this integration can enhance the sustainability and cultural significance of these traditional crafts.

Data availability statement. Data available on request from the authors – The data supporting this study's findings were collected during field research and available from the corresponding author, Debarati Das, upon reasonable request.

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