ABSTRACT
This paper examines the intersection of sustainable education, cultural heritage preservation, and artistic representation by exploring the process of creating bio-jewelry from fish scales dyed with natural pigments, detailing the methodology of utilizing locally sourced materials, emphasizing the role of traditional knowledge in dye extraction from plants such as Urucum (*Bixa orellana*) and Earth Saffron (*Curcuma longa*). The shift from synthetic to natural dyes was shown to mitigate environmental concerns and empower local communities. Aligned with UN Sustainable
INTRODUCTION

In the 21st century, the importance of sustainable practices, inclusive education, and protection of traditional cultures has been recognized worldwide. The 2030 Agenda for Sustainable Development, adopted by the United Nations in 2015, sets 17 global goals for sustainable development, with a focus on education and the promotion of innovative educational practices, conscientious production, and waste containment (UN General Assembly, 2015). Within this framework, the convergence of arts, education, and cultural preservation is proving to be an effective means of disseminating knowledge, promoting cultural diversity, and enhancing ecological awareness.

In recent years, the instruction of art within rural communities in Brazil has undergone a notable expansion. This growth has brought forth fresh models and educational paradigms, all rooted in addressing the genuine needs of the people, their traditions, local materials, and accumulated wisdom. Central to these approaches is a fundamental shift: education is no longer centered solely on the transmission of knowledge. Instead, it embraces a dynamic that fosters the
creation and construction of knowledge, emphasizing the cultivation of possibilities for independent production and learning.

Traditional knowledge stands as a vital resource, contributing to diverse facets of sustainable development and cultural preservation. Its significance is underscored by its capacity to provide invaluable insights into sustainable resource management, conservation practices, and the preservation of biodiversity (Saylor et al., 2017). Despite its paramount importance, the traditional knowledge held by these communities often remains underappreciated and undervalued due to a misalignment between their aspirations and the trajectories of public policies and government actions (Morais and Silva, 2010).

A sustainable future requires that we live in harmony, freedom, and prosperity while caring for the well-being of ourselves and future generations. Education for Sustainable Development (ESD) seeks to empower people of different ages, genders, and cultures to explore a range of ideas for achieving sustainability and to participate in making their visions a reality (Arsakahova, 2023). It also recognizes the importance of cultivating not only technical skills, but also a comprehensive understanding of the interactions between society and the environment (Versuti et al., 2020). Moreover, novel educational processes are indispensable for the effective implementation of public policies that uphold the fundamental rights of all citizens. This requires not only the introduction of new technologies, but also the reformulation of teaching methods (Pazos et al., 2023).

Consequently, the promotion of an education that goes beyond the mere transmission of information has taken a central place in academic discourse. At the same time, the preservation of cultural heritage is of immense importance in maintaining the identity and history of marginalized communities, especially in the face of cultural globalization (Lovtsova et al., 2021). In this context, commitment to the UN Sustainable Development Goals (SDGs), including Goal 4 (Quality Education) and Goal 12 (Responsible Consumption and Production), underscores the importance of pioneering educational practices that integrate sustainable principles and foster appreciation for local cultures.

In 2016, the Federal Institute of Paraiba (IFPB), in collaboration with the Brazilian Federal Government's National Program for Access to Technical Education and Employment (PRONATEC) and the Extension Nucleus in Territorial Development (NEDET-UFPB), embarked on a pioneering initiative through the launch of the "Bio-Jewelry Craftsman" course.
This comprehensive endeavor was designed to transmit techniques and technologies for crafting bio-jewels, with a multi-faceted purpose: to fortify cultural identity, mitigate the environmental footprint stemming from fishing waste and synthetic dyes, broaden avenues for income generation, and empower the social and economic autonomy of young individuals and indigenous women from the villages Ibikuara, Três Rios, and Tramataia, of the Potiguara Indigenous People in Marcação, as well as artisanal fisherwomen from Barra de Mamanguape in Rio Tinto, within the Territory of Zona da Mata Norte in Paraíba, Brasil.

The growth of the global population, urbanization, and industrialization has led to a significant increase in both fisheries and aquaculture production. As a result, a substantial amount of fish waste is generated worldwide, presenting economic and environmental challenges (Coppola et al., 2021). In the context of heightened focus on the circular economy and the global pursuit of sustainable methodologies, there has been a noticeable upsurge in the exploration of alternative material sources. This trend places a distinct emphasis on harnessing the potential of underutilized or discarded marine materials as a robust and ecologically aware strategy.

The discipline "Bio-Jewelry Design Using Fishing Waste" within the "Bio-Jewelry Craftsman" course exemplifies this forward-looking stance by repurposing fish waste to craft distinctively dyed jewelry. Nevertheless, as society embraces these environmentally friendly strategies, it becomes crucial to confront the drawbacks associated with traditional practices. One significant concern pertains to the application of synthetic dyes and the resulting environmental consequences.

Since their introduction, synthetic dyes have garnered widespread popularity owing to their ease of application, resistance to fading, and capacity to replicate a broad array of colors without demanding intricate upkeep processes (Pizzicato, 2023). These characteristics have spurred their swift integration across diverse sectors, ranging from textiles to plastics, thereby contributing to the dynamic and multifarious hues that define contemporary consumer products.

Nonetheless, the convenience offered by synthetic dyes comes accompanied by a substantial toll on the environment and public health. The majority of synthetic dyes originate from petrochemicals, which are obtained from fossil fuels and carry adverse ecological consequences. The synthesis of these dyes involves intricate chemical reactions that not only consume significant amounts of energy but also yield hazardous byproducts. Frequently, these
byproducts infiltrate water bodies and soil, leading to pollution that disrupts ecosystems and undermines the purity of drinking water (Manzoor and Sharma, 2020).

In response to these environmental and health-related challenges, the investigation of natural alternatives for dyeing applications has gained significant momentum in recent years. Natural dyes, sourced from various plant materials, minerals, and even insects, offer a promising avenue for achieving vibrant and diverse color options without the negative ecological consequences associated with synthetic dyes.

Moreover, the utilization of these natural sources can promote local economies, preserve traditional knowledge, and foster a deeper connection between cultural heritage and contemporary design. As industries and consumers increasingly prioritize eco-friendly choices, the exploration of natural dyeing methods stands as a significant stride towards a more sustainable and harmonious relationship with the environment (Santos and Carvalho, 2022).

The present study seeks to detail the techniques used in coloring the scales of local fish using natural dyes cultivated and consumed in the region. It is hoped that the analysis of this process will contribute to the understanding of sustainable educational practices and cultural preservation, in addition to offering insights for future initiatives that seek to unite these two domains effectively.

2 METHODOLOGY

Through participatory planning involving the students of the course, local natural resources that would be used were identified. This strategic selection of fish and natural dyes not only facilitated the execution of practical activities but also strengthened the connection with the local culture and highlighted the available resources in the region.

2.1 SELECTION AND COLLECTION OF RAW MATERIALS

Initially, the gathering of raw materials for the fish scale coloring process was conducted through field visits to the surrounding areas of Aldeias Ybykuara, Três Rios, Tramataia, and Barra de Mamanguape.

Scales from the Camurupim (Megalops atlanticus) and Hake (Cynoscion spp) fish were chosen. Camurupim scales were collected along the banks of the Mamanguape River, a frequent anchoring site for fishing vessels from Aldeia Tramataia. Hake scales were acquired at the fish
market in Baía da Traição, an adjacent municipality that encompasses various Potiguara People's Villages in Paraíba.

The natural dyes selected for the coloring process included Urucum (*Bixa orellana*), which is cultivated within the villages and commonly employed in traditional ethnic body painting. Additionally, Earth Saffron, (*Curcuma longa*), Indian Clove (*Syzygium aromaticum*), and Beetroot (*Beta vulgaris*) were utilized. These materials were sourced from both the students' kitchens and local establishments such as grocery stores.

### 2.2 CLEANING OF THE FISH SCALES

To ensure the thorough elimination of residues and impurities present in the collected fish scales, a solution comprising 250 ml of sodium hypochlorite and 30 g of powdered soap was prepared. Sodium hypochlorite is a chemical compound with strong disinfectant properties that can effectively remove mucus or other undissolved material from fish scales (Hedayati *et al.*, 2021). This formulation was subsequently diluted with water until reaching a total volume of 2 liters. The scales were fully immersed in this solution, with distinct immersion durations set for each fish variety: 12 hours for Camurupim scales and 2 hours for Hake scales. Following the immersion period, the scales were meticulously rinsed under flowing water to eliminate any potential chemical remnants.

To address adhered muscle tissue residues on the Camurupim scales, a small knife served as an auxiliary tool for removal. Afterward, the scales underwent treatment with a fresh solution consisting of 2 liters of water and 20 grams of soap powder, remaining immersed for a duration of 2 hours. At the conclusion of this timeframe, the liquid component of the solution was separated using a sieve. Subsequently, the scales were rinsed under running water to eliminate any lingering chemical remnants. Finally, the scales were positioned on paper and subjected to a shaded drying process.

### 2.3 EXTRACTION OF NATURAL DYES

The subsequent stage of the process involved the extraction of natural dyes intended for coloring the scales, drawing upon insights gained from ancestral knowledge and prior experimentation. This reliance on traditional knowledge embodies generations of wisdom and practical understanding, enriching the process with sustainable and culturally rooted techniques.
The dyes were extracted using ethyl alcohol, as it is an eco-friendly solvent (Giridhar et al., 2014).

To extract the annatto dye, the seeds of six fruits were immersed in 50 ml of ethyl alcohol for a duration of two days. For the Indian Clove dye extraction, 40 g of the substance were immersed in 250 ml of ethyl alcohol over a three-day period. To extract the Earth Saffron dye, 10 g of plant powder were immersed in 50 ml of ethyl alcohol for a duration of six hours. Finally, for beet coloring, the beet skins were boiled in 250 ml of water for 20 minutes at a temperature of 180°C.

2.4 FISH SCALES COLORING

For coloring the scales, two distinct techniques were employed: single-color staining and dual-color staining.

*Single-color staining. Regarding the Earth Saffron extract, the scales were immersed for a period of 12 hours. For the Annatto, Indian Clove, and Beetroot extracts, the scales were submerged for five days. Following this, the scales underwent individual sieving to extract the liquid component of the extracts. Subsequently, the colored scales underwent a washing process in a solution comprising 500 ml of water and 100 ml of vinegar to set the color. The final step of this stage involved drying the scales on paper in a shaded area.
Figure 1 – (a) Camurupim scales immersed in the sanitizing solution. (b) Camurupim scales with beetroot (darker liquid) and annatto (yellow liquid) dyes.

Source: Authors.

**Dual-color staining.** The previously sanitized scales of the Camurupim fish were employed. Initially, a small quantity of annatto extract was placed in a glass, and one end of the scales was submerged for six hours. After this timeframe, the scales were taken out and positioned on paper to dry in a shaded area.

Following this, the uncolored section of the scales were submerged in a small quantity of beetroot extract, contained in a separate container, for an additional period of five days. After this interval, the scales were removed from the extract, rinsed under running water, and subsequently washed in a solution consisting of 500 ml of potable water and 100 ml of vinegar, to fix and enhance the color of the dyes (Bose, 2015). The stage was finalized by allowing the scales to dry on paper in a shaded setting.
2.5 WASTE CLASSIFICATION

The residues resulting from the process, encompassing both organic and chemical remnants from the scale cleaning and coloring, were categorized in accordance with the ABNT NBR 10004:2004 standard.

3 RESULTS AND DISCUSSION

By tapping into the rich legacy of traditional knowledge in the region, which has been passed down through generations, students were able to identify and utilize specific plant materials that hold inherent dyeing properties. This highlights the practical relevance of traditional wisdom, which often encompasses an intricate understanding of local flora and their potential applications (Morais and Silva, 2010). Table 1 presents a comprehensive overview of the extracted dyes, corresponding species, and the resultant colors achieved. Dyeing parameters such as immersion duration, dye concentration, and inherent characteristics of the natural dye sources played crucial roles in determining the intensity and variability of the colors achieved. Notably, the longer immersion periods yielded more intense colors.

<table>
<thead>
<tr>
<th>Natural Source</th>
<th>Scientific Name</th>
<th>Obtained Color</th>
<th>Cultural Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urucum (Açaí)</td>
<td><em>Bixa orellana</em></td>
<td>Red</td>
<td>Traditional body painting</td>
</tr>
<tr>
<td>Açafrão da Terra (Earth Saffron)</td>
<td><em>Curcuma longa</em></td>
<td>Yellow</td>
<td>Culinary and ritual use</td>
</tr>
<tr>
<td>Cravo-da-Índia (Indian Clove)</td>
<td><em>Syzygium aromaticum</em></td>
<td>Brown</td>
<td>Medicinal properties</td>
</tr>
<tr>
<td>Beterraba (Beetroot)</td>
<td><em>Beta vulgaris</em></td>
<td>Deep Red</td>
<td>Culinary and cultural use</td>
</tr>
</tbody>
</table>

Source: Authors.

This utilization of locally sourced resources not only imparts aesthetic allure but also reinforces the cultural significance of the bio-jewelry. It establishes an intricate link between each piece and a narrative deeply ingrained in the heritage of indigenous communities, cultivating a stronger connection between students and the undertaken activities. This connection facilitates a richer engagement with the creative process.
Shifting from synthetic to natural dyes addresses the pressing environmental concerns associated with chemical dyes derived from petrochemicals. Moreover, the incorporation of traditional dyeing practices enhances the socio-economic autonomy of indigenous women and artisanal fisherwomen, fostering a sense of empowerment and agency. This move toward sustainable bio-jewelry production aligns seamlessly with the United Nations Sustainable Development Goals, notably Goal 12 (Responsible Consumption and Production) and Goal 5 (Gender Equality).

Furthermore, the "Bio-Jewelry Craftsman" course imparts sustainable dyeing techniques and paves the way for wider applications. This approach not only imparts practical skills but also instills a deeper appreciation for sustainable practices among the youth. Integrating indigenous knowledge into education not only supports the preservation of cultural identities but also equips the younger generation with tools for sustainable innovation.

According to ABNT NBR 10004:2004, organic and chemical residues from the cleaning and coloring process of the scales are classified as non-hazardous (A099 - class II) as the biodegradability of natural dyes ensures that the end-of-life disposal of dyed materials is less harmful to the environment.
4 CONCLUSION

The confluence of sustainable practices, indigenous knowledge, and artistic expression in the context of bio-jewelry creation through natural dyeing of fish scales offers a transformative approach to education, culture, and environmental consciousness. Through the innovative "Bio-Jewelry Craftsman" course, the study has illuminated the potential of uniting traditional wisdom, contemporary design, and ecological responsibility. The diverse array of colors achieved through the fusion of fish scales and natural dyes not only enhances the visual allure of the bio-jewelry but also deepens its cultural and ecological significance.
REFERENCES


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