Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

Exploration of the Manufacturing Process and Selection Method of Natural Dyes in Eco-print: Ethnoscience Implications in Chemistry Learning

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ABSTRACT Students' lack of understanding and ability to conceptualize chemistry material in real life requires an effort to integrate chemistry learning with cultural values or local wisdom. One such effort is the process of making eco-prints. This research aims to uncover the ethnoscience aspects (chemistry) involved in producing and selecting eco-print natural colors that can be used in chemistry learning. This research focuses on the chief and his four crews or core employees of the Batik Craftsmen Community "Hamparan Rintik," which is actively involved in producing and marketing various batik in Malang City. This research utilizes a qualitative descriptive approach with ethnographic methods. Data sources were gathered through observation, interviews, and documentation. Data analysis was conducted using triangulation of data sources and the NVIVO 12 software. The results revealed important aspects of making eco-prints, including mordanting, coloring, and fixation. The steaming technique is commonly used in eco-printing. Moreover, the natural dyes frequently used in eco-prints are Indigofera leaves for blue, tingi bark for brown, and tegeran wood for yellow. The eco-print motifs often utilize natural materials such as red teak leaves, lanang leaves, castor leaves, genitri leaves, and African wood leaves. This research has implications for learning chemistry, including the concepts of solution-making, chemical reactions and structures, acid-base reactions, thermochemistry (heat transfer), and the nature of hygroscopic compounds.

Keywords: Chemistry, Eco-print, Ethnoscience, Natural dyes

1. INTRODUCTION

Chemistry learning often faces challenges due to a lack of contextualization, which can hinder student engagement and understanding of the subject matter. The lack of contextualization in chemistry learning resources is a significant problem (Wahyudiati, 2022). Integrating contextual examples, laboratory work, and multimedia into chemistry learning materials has been proposed to overcome this challenge and increase student engagement (Sinaga et al., 2019). Additionally, the application of ethnoscience in chemistry learning has been recognized as a means to make the subject more enjoyable and relevant to student's daily lives, thus improving their engagement and understanding. Using contextual learning resources, such as local wisdom, allows students to explore chemistry in a familiar and authentic setting, fostering a deeper understanding of chemical principles (Sutrisno et al., 2020).

Ethnoscience integrates traditional knowledge and cultural practices into scientific learning. Incorporating ethnoscience into chemistry education has positively impacted student perceptions, critical thinking skills, and science literacy (Laksono et al., 2023; Rushiana et al., 2023). Moreover, the integration of ethnoscience in chemistry education is associated with increased character values and conservation behavior among students (Utari et al., 2020; Sudarmin et al., 2019; Sumarni, 2018). This approach enriches the learning experience and fosters the development of entrepreneurial character and problem-solving skills in students (Sudarmin et al., 2019; Rizaldi et al., 2021). Using ethnoscience-based learning materials, such as those that combine natural products and traditional practices, bridges scientific concepts and real-life contexts, making it easier for students to integrate various materials into science learning (Rizaldi et al., 2021).

Eco-print can be considered an example of ethnoscience-based learning, which integrates indigenous

Received: 23 January 2024
Revised: 18 July 2024
Published: 30 November 2024

knowledge into scientific learning materials. Eco-print is a technique that involves transferring the shapes of natural materials onto fabric, utilizing indigenous knowledge of dyes and materials to create visually appealing and environmentally friendly designs (Nurmasitah & Sangadah, 2023). This process aligns with the principle of ethnoscience, which integrates traditional knowledge with scientific practices, providing a concrete example of how indigenous knowledge can be incorporated into scientific learning materials. The quality of eco-print products, including motifs, colors, and fastness, is assessed by the type of mordant, natural dyes, and leaf types, demonstrating diverse eco-print properties (Wahyuningsih et al., 2022).

Eco-printing potentiates ethnoscience-based chemistry learning and sustainable education by merging indigenous knowledge with scientific inquiry. This technique involves transferring natural material patterns onto fabric using traditional dyeing methods, which creates aesthetically pleasing and eco-friendly textiles and deepens learners' understanding of ecological relationships and cultural heritage (Nurmasitah & Sangadah, 2023). Research has demonstrated that eco-printing can significantly enhance creativity, environmental stewardship, and problem-solving abilities (Lo, 2024). Additionally, the integration of eco-printing into chemistry curricula, as seen in the initiatives by The Daunan brand can educate participants and foster a deeper environmental consciousness (Musrifah, 2023). Eco-printing aligns with the principle of ethnoscience, which integrates traditional knowledge with scientific practices, providing a concrete example of how indigenous knowledge can be incorporated into scientific learning materials by the type of mordant, natural dyes, and leaf types (Wahyuningsih et al., 2022). Collectively, these studies underscore the transformative potential of eco-printing in ethnoscience-based chemistry education in enhancing cultural awareness and providing opportunities for developing scientific reasoning skills.

This research aims to provide an overview of the local wisdom of community groups (batik artisans named Hamparan Rintik community) in Malang City and its implications for chemistry learning. The urgency of this research is to provide a potential solution to the problems of chemical education by integrating ethnography into the learning process. This way, the learning process is based on the context of students' lives with cultural aspects as the substance of understanding chemical concepts that originate from a region's values of local wisdom. This research is hoped to contribute not only to the development of student's cognitive aspects but also to affective and psychomotor aspects, which are very relevant to the demands of 21st-century learning. Based on the problems and explanations that have been mentioned, the formulation of the research questions is as follows:

Research Question 1: What are the steps involved in the process of making an eco-print?

Research Question 2: How are natural dyes selected for use in eco-prints?

Research Question 3: What are the implications of the eco-print manufacturing process and the selection of natural dyes for chemistry education?

Additionally, this research aims to establish a connection between the value of local knowledge in eco-print production and chemistry. It is crucial to conduct this research to uncover the chemical aspects underlying the eco-print production process in the Hamparan Rintik Community and incorporate relevant knowledge from this process into chemistry education.

2. METHOD

2.1 Research Design

This research was conducted using a descriptive qualitative approach with ethnographic methods. Creswell (2002) defines ethnographic research as qualitative research in which researchers describe and interpret patterns of values, behavior, beliefs, and language shared and learned from cultural groups. Data collection for this research was carried out using observation, interviews, and documentation techniques. The data gathered in the research consists of information related to the phenomenon under study. The research object chosen was a batik craftsman, Hamparan Rintik, in Malang City, East Java Province. As the first step of the research, the researcher conducted observation and documentation at the research location. Furthermore, data regarding the eco print-making process were collected from interviews with participants from the Hamparan Rintik Community.

The ethnographic research method begins with the stages of (1) determining whether ethnography is an appropriate design for studying the research problem, (2) identifying and locating a culture-sharing group to study, (3) selecting a cultural theme, issue or theory to be studied by the group, (4) determining the type of ethnography to be used to study cultural concepts, (5) collecting information in the context or setting in which the group works or lives, (6) generating an interpretation of the group's culture as a whole from the analysis of patterns across multiple data sources, and (7) presenting the group's patterns of cultural sharing in a written or performance format, done by representing the data obtained from notes during oral and written interviews (Creswell, 2002).

Figure 1 Analysis technique of the data obtained

2.2 Setting and Participants

The research setting for this study is MT Haryono Street, number 870 Dinoyo, Malang City, East Java, Indonesia. The participants in this research are members of the Hamparan Rintik Community, which consists of the chief of Hamparan Rintik, who has four crews or core employees of batik craftsmen. The community was established in 2017 and has participated in several training courses on various types of batik and eco print. Therefore, the data obtained from this community have high credibility, as the informants are experienced in making eco prints.

2.3 Data Source

The data sources used in this study are as follows: (1) interviews with the Hamparan Rintik Community. Researchers conducted oral communication with selected participants based on specific criteria to obtain rich, detailed, and varied data about their attitudes, values, and experiences. (2) Observation was also conducted to directly observe the activities and interactions that take place in the field. (3) Documentation was collected at the location of the batik artisans of the Hamparan Rintik Community to obtain more detailed data on the location representation and the process of making eco-prints. Transcripts were made from the data obtained through interviews, observations, and documentation for further analysis.

2.4 Data Analysis Technique

The research procedure used to analyze the data is inductive data analysis, which involves analyzing the data obtained at each step of making eco-prints specifically and then describing them in a general manner by linking the chemical aspects used in the process. The data obtained is transcribed to facilitate the analysis process. Before transcribing the interview data, it is confirmed with the participants to avoid any errors in data analysis. In addition to manual analysis, the transcript results are further analyzed using the NVIVO 12 application to provide a more detailed representation of the data. The stages of the data analysis are described in Figure 1.

3. RESULT AND DISCUSSION

The eco-print technique is a simple printing method that uses natural dyes on fabric to produce unique and authentic patterns from materials such as leaves and flowers (Jazariyah et al., 2023). According to observations and interviews with participants, the usual eco-printing process carried out by Hamparan Rintik Batik Craftsmen involves pounding and steaming. The pounding technique is simple for creating eco-print patterns on fabric using a wooden hammer. This method is carried out by placing several leaves or flowers on the fabric and then pounding them with a wooden hammer. Meanwhile, the steaming technique is carried out by steaming the fabric adorned with various plant materials, then rolling it up, covering it with a blanket or plastic, tying it securely, and finally steaming it. The steaming technique utilizes steam and heat to transfer the color and shape of the plants on the fabric.

During the pounding stage, pigment transfer occurs where the pounding helps break down leaf cells, allowing natural pigments to be released and transferred to the fabric. Additionally, the use of mordants in both the pounding and steaming techniques serves to bind pigments to the fabric fibers and enhance colorfastness against washing and sunlight by forming coordination complexes with the dyes that adhere to the fabric. Mordants are always polyvalent metal ions. The resulting dye and ion coordination complexes are colloidal and can be acidic or basic. Mordants can be added before, during, or after the

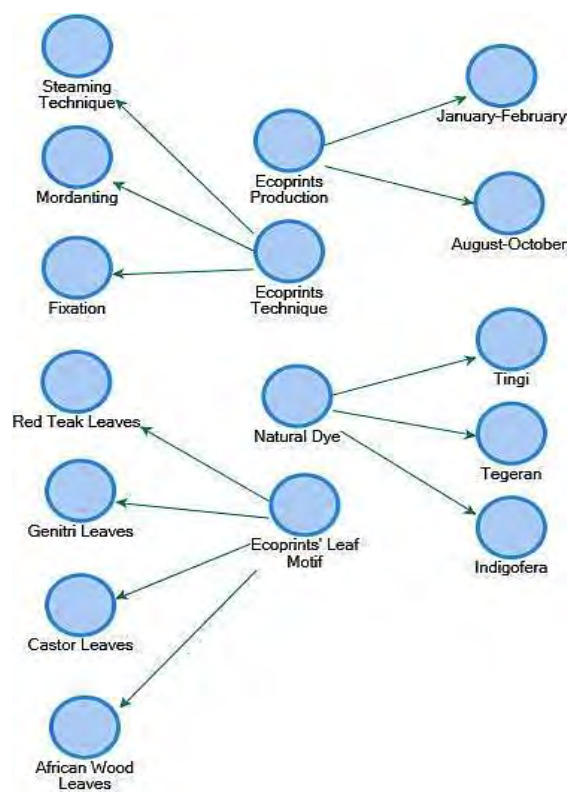


Figure 2 NVIVO 12 analysis results

dyeing process, with most mordants typically applied before dyeing.

Before entering the core stage of eco print-making, the community and participants involved in the activity must conduct a fabric purification process to remove components that can inhibit color absorption. The output obtained from NVIVO 12 software is a project map that identifies and visualizes the relationship between concepts in the research, as presented in Figure 2.

The eco-printing processes are strongly related to critical chemistry concepts and have potential for chemistry education. The NVivo analysis reveals a complex interplay of factors influencing the eco-printing process. This intricate relationship between various components presents a rich opportunity to explore fundamental chemistry concepts. At the core of eco-printing lies the extraction of color from plant materials, a process deeply rooted in chemistry. The choice of leaves, such as teak, genitri, castor, and African wood, introduces the concept of natural dyes and their chemical composition. Using mordants to fix the color involves chemical reactions that enhance color fastness and durability.

Moreover, the timing of eco-printing production, divided into January-February and August-October, suggests potential variations in dye extraction efficiency due to seasonal changes in plant chemistry. This observation opens avenues for investigating environmental factors' impact on chemical processes. Furthermore, the steaming technique employed in eco-printing involves heat and pressure, which can alter the chemical structure of both the dye and the fabric fibers, providing opportunities to study the effects of physical and chemical changes on materials (Satria et al., 2024; Tkalec et al., 2024). The eco-printing process offers a tangible and visually appealing platform to explore a wide range of chemistry concepts, from organic chemistry and color theory to physical chemistry and environmental science. By delving into the underlying chemical mechanisms, educators can create engaging and interdisciplinary learning experiences that foster a deeper understanding of chemistry's relevance to the natural world (Jazariyah et al., 2023).

3.1 Eco-printing Process: Mordanting, Fabric Coloring, and Fixation

The eco-printing process utilizes natural materials and techniques to create various products, such as batik bags and current fashion trends. The use of natural dyes and eco-print techniques has been proven to increase creativity and economic potential in the community (Bahtiyari et al., 2013; Saad et al., 2021; Ayu et al., 2022; Irdalisa et al., 2023). The eco-print process is also considered more environmentally friendly because it does not disturb the surrounding ecosystem (Kurniati et al., 2021). The materials used also come from natural sources, such as leaves and flowers, to minimize the use of excess chemicals. The eco-print technique involves several stages, including scouring, mordanting, printing, and natural dye extraction, which contribute to the quality and environmental friendliness of the final product (Ardianto, 2021; Nurmasitah & Sangadah, 2023; Glogar et al., 2020).

Eco-print techniques include various methods such as steaming, pounding, and boiling (Nurmasitah & Sangadah, 2023). As mentioned in the interview, "Broadly speaking, there are two techniques used, namely pounding and steaming techniques. The working process of eco-print is transferring the tannin content of the leaves on the plant to the fabric. This transfer process is assisted by pressure, either by pounding or steaming (utilizing hot temperatures)." The Hamparan Rintik community primarily uses steaming techniques, as stated by the participant, "Hamparan Rintik uses more steaming techniques because the steaming process is faster and can be done in large quantities.

In contrast, using the pounding technique takes a bit more time". The steaming method in eco-printing is considered cheap, easy, and simple to practice, making it accessible to practitioners. Additionally, research has shown the effectiveness of the steaming method in eco-printing on various materials, achieving good average color friction resistance. This result demonstrates the versatility of the steaming method in eco-printing and its potential to produce high-quality results.

The interviews also provided information regarding the process of making eco-prints, which involves several necessary steps. First, the fabric must be scoured to remove dirt and prepared for dyeing. After scouring, the fabric is mordanted to ensure the effective absorption of natural dyes, thus contributing to maximum color absorption and the quality of the resulting print. As stated by the participant, "Before eco-printing, the fabric must first be mordanted or mineral loaded. To maintain the fabric, we use soda ash, baking soda, alum, arbor (iron sulfate), and vinegar."

The next step involves the actual eco-print process, where colorful plant parts are directly placed on the natural fiber fabric, followed by boiling to transfer the color and shape to the fabric as presented in Figure 3. Finally, a fixation process is carried out to ensure the durability of the print on the fabric (Ayu et al., 2022; Wirawan & Alvin, 2019). Based on this, three core activities are carried out in eco-print production, including mordanting (pre), fabric coloring, and fixation (post) activities. These processes exemplify various chemical concepts, such as molecular interactions during mordanting, chromatographic principles during fabric dyeing, and polymerization in color stabilization during fixation. The mordanting process explores various chemical concepts, namely molecular interactions, where the binding of natural dyes to fabric fibers in the mordanting process incorporates molecular interaction and bonding. In addition, the mordanting process also involves chemical coordination bonds, where

(a) (b)

Figure 3 (a) The arrangement stage of the motif using leaves; (b) The drying stage on the eco-print (Source: Personal Documentation Hamparan Rintik)

metal salts often form coordination bonds with dye molecules.

Then, during the fabric dyeing stage, the redox properties of some metal ions can also play a role in dye extraction. The fabric dyeing stage in eco-printing contains various compounds, including tannins, flavonoids, anthocyanins, and chlorophyll, which implements phytochemistry. The molecular structure of natural dyes determines the color outcome and affinity for fabric fibers. The process of dye transfer from plant material to fabric involves chromatographic principles, as different compounds migrate at different rates. The last is the fixation process. In eco-printing, some compounds in the plants used for dyeing can undergo polymerization when exposed to heat or certain chemicals during the fixation process, which can help strengthen the bond between the dye and the fabric fibers. These three activities must be carried out sequentially and to produce excellent and optimal eco-print products. After the three core activities are completed, the final step is the eco-print drying process.

3.2 Types of Natural Dyes Used in Eco-printing

The selection of natural dyes is a crucial part of the mordanting and fixation process, which aims to enhance color intensity and strengthen the bond between fibers and dyes, which helps prevent color pigments from fading (Sofyan et al., 2015). The Hamparan Rintik Community commonly uses natural Indigofera, tingi, and tegeran dyes, as shown in Figure 4. According to the interview results, "We primarily use Indigofera leaf paste for blue, tingi bark for brown, and tegeran and mer wood for yellow." As a result, the natural dyeing process in the Hamparan Rintik Community tends to produce shades of blue, brown, and grey, but not red like secang. Secang contains brazilin, which is red and is soluble in water. This solubility results in the red color of secang being less stable, causing much of the color to wash out during the fixation stage, making the final color less appealing (Pujilestari & Salma, 2017).

Furthermore, they mentioned that their consumer research showed that red color enthusiasts prefer jreng (vibrant) colors that cannot be achieved with natural dyes. Therefore, the Hamparan Rintik Community does not frequently use red natural dyes. After coloring with natural dyes, they proceed with the fixation process using arunjung. According to the participant, "For the leaves themselves, we use a lot of red teak leaves, lanang leaves, castor leaves, genitri leaves, and African wood leaves for eco-print, with arunjung as the fixation agent." Arunjung is

Figure 4 Coloring process with Indigofera leaf natural dye (Source: Personal Documentation of Hamparan Rintik)

Figure 5 The finished eco-print result (Source: Personal Documentation Hamparan Rintik)

a safe material that produces vivid colors and binds them to the fabric. The final eco-print is displayed in Figure 5.

3.3 Ethnoscience: Integration of Local Wisdom and the Implications of Eco-print Natural Coloring Process and Use for Chemistry Learning

Natural dyes provide an excellent opportunity to integrate chemistry learning with sustainable and environmentally friendly practices. Incorporating natural dyes into chemistry education allows students to gain practical knowledge of organic, inorganic, and analytical chemistry (Machado et al., 2022). By engaging in activities such as dyeing natural fabrics with mordants, students can explore the chemical processes involved in dyeing and develop an understanding of green chemistry principles and environmental science (Machado et al., 2022). Additionally, using natural dyes can bridge the gap between traditional chemistry concepts and their real-world applications, fostering a deeper appreciation for the relevance of chemistry in everyday life (Pereira et al., 2006).

Interviews revealed commonly used natural dyes include Indigofera leaves, tingi bark, tegeran wood, and merr wood. The chemical compounds found in Indigofera leaves contribute to their potential as natural dyes. Ariyatun et al. (2022) identified indigo, flavonoids, steroids, and alkaloids as essential components in Indigofera tinctoria leaves for use as natural textile dyes. By identifying and analyzing the chemical compounds present in Indigofera leaves, such as indigo, flavonoids, steroids, and alkaloids, participants can gain a practical understanding of phytochemistry and the role of these compounds in natural dye production. Participants can also measure the color intensity of different dye extracts, which can indirectly introduce the concepts of absorbance and concentration.

The concept of chromatography also plays a role in eco-printing, where different components of plant extracts can be separated using the chromatographic principle that different compounds have different affinities for the stationary phase (Simion Beldean-Galea et al., 2018). The effect of pH on dye extraction and color development can also be investigated, indirectly introducing the concepts of acid-base chemistry. Green chemistry concepts can be learned through the use of natural dyes from the environment more effectively than synthetic dyes, as natural dyes are biodegradable and can reduce water pollution. Methods for extracting dyes without harming the plant or its ecosystem also incorporate green chemistry concepts and sustainable practices.

Furthermore, Ariyatun et al. (2022) explained that the glucoside content of indikan in Indigofera plants, when soaked in water, undergoes a hydrolysis process facilitated by enzymes, converting indikan into indoxyl (white tarum) and glucose. Indoxyl can be oxidized to blue tarum, as shown in Figure 6. Additionally, Campos et al. (2018) provided a comprehensive review of the phytochemistry of Indigofera suffruticosa, highlighting the plant's diverse chemical composition. These studies collectively

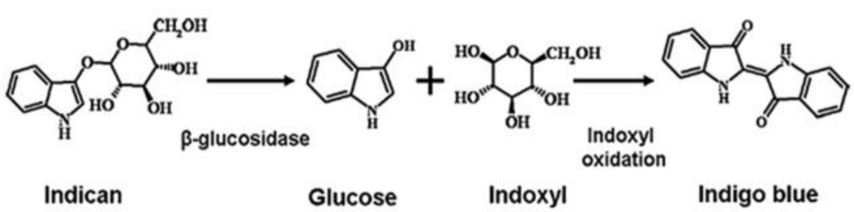
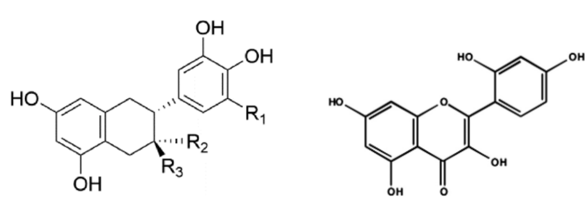


Figure 6 Indikan hydrolysis reaction (Source: Kim et al., 2009)



(a) (b)

Figure 7 (a) Flavan-3-ol compound (Source: Rousserie et al., 2019); (b) Morin compound (Source: Wei et al., 2015) demonstrate the presence of various chemical compounds in Indigofera leaves that are essential for their potential use as natural colorants.

Furthermore, a natural dye that is often used is derived from tingi bark (Ceriops candolleana). The bark of Ceriops candolleana is used as a source of natural dye, particularly for producing a brownish color known as soga brown. Firmansyah (2020) identified that there are catechin compounds in the form of flavan-3-ol in the bark of Ceriops candolleana. Meanwhile, tegeran wood (Cudrania javanensis) contains flavonoids, alkaloids, steroids, saponins, and tannins (Swargiary & Ronghang, 2013). The main flavonoid in tegeran wood is morin, which gives silk its yellow color (Kongkiatpaiboon et al., 2016; Septhum et al., 2007). These findings contribute to understanding the molecular structure of natural compounds in Cudrania javanensis, which can be used for fabric dyeing applications. Structural images of Flavan-3-ol compounds and Morin compounds are presented in Figure 7.

The next concept in chemistry is implicated in the eco-print fixation process using an arbor material. The arbor used in eco-print production is made by utilizing pre-treated arbor crystals, making their use more efficient. Arbor is commonly in the form of crystals or powder with a faded green color, resulting in shades of brown towards green. Conifers produce sharp colors and bind them to the fabric due to the hygroscopic properties of arbors. Hygroscopic compounds could absorb water from the surrounding environment. This property can be found in various types of compounds, both organic and inorganic.

Research by Kusumaningtyas and Wahyuningsih (2021) explains that arbor use has the advantage of producing well-printed and intense motif colors, making the leaf veins visible. Conifers have the chemical formula $FeSO_4$ and are soluble in water to form a solution. Water is a solvent that dissolves the solute (arbor) in making the arbor solution. In addition, the arbor has a high concentration, so the arbor is dissolved using a ratio of 1:2 (1 liter of water: 2 grams of arbor).

The concept of acid-base is also utilized in the eco-printing method. In the initial eco-printing stages, mordanting must use various solutions, including vinegar. Vinegar has the chemical formula CH_3COOH and is a weak acid that increases the acidity level of the medium (fabric). This acidity plays a role in strengthening the bond between natural dyes and fabric fibers. Moreover, vinegar can prevent unwanted color changes in the fabric, preserving the natural color of eco-printed plants. A fixation process is required after the dyeing process to achieve good stability in the fabric. Fabric fixation often involves the use of alum with the chemical formula $FeSO_4$. Alum has alkaline (basic) properties that maximize color absorption in fabric fibers and achieve pH stability.

The final step in eco-printing is the drying process, which exemplifies the application of thermochemical concepts, specifically the transfer of heat. Thermochemistry encompasses the concepts of endothermic heat transfer (the system absorbs heat from the surroundings) and exothermic heat transfer (the system releases heat to the surroundings). The drying process falls under the exothermic process, characterized by an increase in temperature that causes initially wet fabric to become dry. Based on the implications of the eco-printing process on chemistry education mentioned earlier, educators are expected to be more adept at connecting chemical concepts to the contextual aspects of everyday life. Thus, the outcome of learning is the successful transfer of knowledge from teacher to student and the attainment of a profound understanding.

5. CONCLUSION

This study suggests that integrating eco-printing with chemistry education can enrich the curriculum by providing a tangible, culturally relevant context for learning chemistry concepts. Natural dyes commonly used in the eco-printing process include Indigofera leaf paste (blue), tingi tree bark (brown), and tegeran tree bark (yellow). These three natural dyes contain various chemical compounds that are beneficial in eco-print production. Findings from this ethnographic research indicate that integrating methods in eco-printing with concepts in chemistry education has numerous implications that can be applied to students' knowledge. This integration enables them to connect the values of local wisdom presented in eco-printing with their understanding of chemistry. The recommendation for practitioners is to enrich chemistry lessons with contextual learning, making them more engaging. The integration of eco-printing into chemistry education can have broader implications for curriculum development.

Eco-printing can serve as a platform for interdisciplinary collaboration between chemistry, biology, and environmental science, fostering a holistic understanding of natural systems. Investigating the chemical properties of natural dyes and the eco-printing process can encourage problem-based learning, where students actively seek solutions to real-world challenges. By combining science (chemistry), technology (eco-printing processes), engineering (dye extraction and application), art (eco-printing motif), and mathematics (data analysis), eco-printing can be a valuable tool for STEAM education. Exploring the cultural significance of eco-printing can promote environmental stewardship and sustainability, aligning with global education goals. Educators can create engaging and meaningful learning experiences beyond traditional textbook content by incorporating these aspects into the chemistry curriculum.

ACKNOWLEDGMENT

Many thanks to the Hamparan Rintik community as the object of this ethnographic research. In addition, the researcher would like to express gratitude to the supervisors who provided valuable knowledge in the qualitative research methods course, enabling the completion of this article.

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