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Development of Natural Dyes Practicum Guidelines Based on Local Sasambo Plants: A Study on Identification and Validation

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Keywords

Development of practicum guidelines, Natural dyes, Sasambo indigenous plants, Chemistry learning

Abstract

This study aims to develop a practicum guidelines for natural dyes based on Sasambo (Sasak, Samawa, Mbojo) indigenous plants to enhance students' understanding of using natural materials as eco-friendly dyes. The environmental hazards posed by synthetic dyes form the background for the importance of this research. The research method used was Research and Development (R&D) with a 4D model approach (Define, Design, Develop, Disseminate). The practicum guidelines includes Sasambo indigenous plants, such as *Ruellia Simplex*, *Curcuma longa*, *Syzygium cumini*, *Areca catechu*, *Pouteria campechiana*, *Clitoria ternatea*, *Cajanus cajan*, *Murraya paniculata*, *Pandanus amaryllifolius*, *Ipomoea batatas*. Expert validation and lecturer evaluations demonstrated that the developed practicum guidelines for natural dyes based on Sasambo indigenous plants is suitable for use. This is evidenced by its high level of clarity, graphical appeal, and usability, enabling effective student engagement with sustainable practices. Field and laboratory analyses identified ten plants capable of producing vibrant colors, such as purple, yellow, red, orange, blue, black, and green, with added antioxidant and antimicrobial properties. The conclusion of this study is that the developed practicum guidelines can be utilized as an effective learning medium for introducing natural dyes derived from Sasambo indigenous plants, thereby contributing to promoting sustainable industrial practices by leveraging local resources for environmental and economic sustainability.

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INTRODUCTION

Natural dyes have been used for centuries in textiles, food, and crafts, offering an alternative to synthetic dyes that often contain harmful chemicals, such as heavy metals. These synthetic dyes are associated with significant environmental and health risks, including water and soil pollution and potential carcinogenicity (Patil et al., 2018; Drioiche et al., 2021). In recent decades, the resurgence of interest in natural dyes has been fueled by growing awareness of the adverse impacts of synthetic dyes and the urgent need for sustainable and eco-friendly solutions (R, 2023; Aggarwal, 2021).

Indonesia, as a tropical country rich in biodiversity, holds tremendous potential for developing natural dyes from its abundant local flora. Plants such as turmeric (*Curcuma longa*), mangosteen rind (*Garcinia mangostana*), and indigofera (*Indigofera tinctoria*) have long been recognized for their vibrant pigments and cultural significance (Wahdina et al., 2021; Sudarmin et al., 2020). In the Sasambo region (Sasak, Samawa, Mbojo), these plants not only serve daily practical uses but also embody deep cultural values. Harnessing this potential is essential, particularly within the educational context, to integrate local wisdom and promote sustainable practices in various sectors, including chemistry education (SAIBA, 2023).

One of the primary challenges in introducing natural dyes to students lies in the lack of teaching materials that incorporate these eco-friendly resources. Most chemistry practicums currently rely on synthetic chemicals that are standardized and readily available (Shamsheer et al., 2021). However, considering the environmental imperatives and the need to foster green technologies, developing practical guidelines that utilize natural dyes from indigenous plants has become critical. Such initiatives not only expose students to sustainable practices but also enhance their understanding of Indonesia's rich natural heritage (Tresnawati et al., 2020; Wahdina et al., 2021).

The Sasambo-based practicum guide seeks to bridge traditional practices and modern methodologies by leveraging the unique properties of local plants. For instance, plants like tarum, coconut, and turmeric produce a spectrum of colors ranging from deep blue to burnt orange. The guide emphasizes the isolation of active compounds such as anthocyanins, curcumin, and chlorophyll, validated with an expert reliability index (Aiken's V) of 0.86, demonstrating its high relevance and applicability (Maulik et al., 2022). This synergy of traditional knowledge and scientific methods fosters creative student engagement and promotes biodiversity conservation through the practical application of natural dyes (SAIBA, 2023).

The extraction and application of natural dyes involve several stages, including the preparation of dye solutions, fabric treatment, dyeing, and fixation. These steps are designed to ensure color quality and durability while providing students with a comprehensive understanding of sustainable practices (Patil et al., 2018; Drioiche et al., 2021). Moreover, the cost-effectiveness and safety of natural dyes further support their adoption as a green alternative to synthetic dyes, although challenges such as variability in dye outcomes and the need for effective mordants remain (Duan, 2024).

This research aligns with global trends advocating for environmentally conscious and sustainable education. Incorporating natural materials into the curriculum raises students' environmental awareness and equips them with practical skills for adopting sustainable practices in daily life (Shamsheer et al., 2021). Thus, this study aims to develop a practical guide for natural dyes derived from Sasambo plants, offering an alternative teaching resource in chemistry education while contributing to environmental conservation and the preservation of local wisdom. This guide includes a range of Sasambo plants, such as *Ruellia simplex*, *Curcuma longa*, *Syzygium cumini*, *Areca catechu*, *Pouteria campechiana*, *Clitoria ternatea*, *Cajanus cajan*, *Murraya paniculata*, *Pandanus amaryllifolius*, and *Ipomoea batatas* (Wahdina et al., 2021).

By integrating these elements, the developed practicum guide not only supports sustainable education but also emphasizes the importance of local biodiversity and its applications in reducing environmental impact while fostering innovation in chemistry education.

METHODS

Research methods

This study utilized the Research and Development (R&D) methodology, implementing the 4D model (Define, Design, Develop, Disseminate) to develop a practical guide on natural dyes derived from Sasambo plants. The 4D model provides a systematic framework for designing educational materials that align with sustainability goals and effectively incorporate local wisdom and green technology (Marchak et al., 2021; Shana & Abulibdeh, 2020).

In the first stage, Define phase, the educational needs for developing the practicum guide were identified. This process involved literature reviews and interviews with chemistry experts and students to ensure the material's relevance and applicability. Additionally, potential Sasambo plants for natural dye sources were determined through literature analysis and consultation with botanical experts. This phase ensured that the guide was tailored to meet the educational objectives of introducing sustainable practices while preserving local biodiversity and cultural heritage (Hernández et al., 2020).

In the second stage, The Design phase focused on structuring the practicum guide into comprehensible sections, including an introduction, objectives, required tools and materials, procedures, and results analysis. A systematic methodology was developed for the extraction and application of natural dyes, ensuring clarity and ease of implementation by students. This phase emphasized aligning the guide's content with modern pedagogical practices to promote critical thinking and hands-on learning (Sharma et al., 2019).

In the third stage, the Develop phase, a prototype of the practicum guide was created based on the designed format. The prototype underwent initial testing with a small group of chemistry students, who provided feedback on its clarity, practicality, and overall effectiveness. This feedback was used to refine the guide further, ensuring it met the requirements of an effective teaching resource. Expert validation was also conducted, with a high reliability index (Aiken's V = 0.86) confirming the guide's credibility and usability (Shana & Abulibdeh, 2020). The feedback from experts and students highlighted the guide's strengths in promoting engagement and understanding of sustainable practices. Specific refinements included enhancing the graphical elements for better visual appeal and adjusting procedural details to ensure consistency.

In the last stage, the Disseminate phase, the finalized guide was implemented on a broader scale across several universities. It was further shared through journal publications and educational seminars to maximize its accessibility and impact. This phase underscored the importance of collaborative efforts in adopting and integrating innovative teaching materials into various educational settings (Marchak et al., 2021).

Research Instruments

The study employed a questionnaire to evaluate the feasibility of the developed practicum guide. The questionnaire was distributed to chemistry experts, botanical experts and lecturers and included three assessment aspects:

Clarity: Evaluating whether the guide's content, language, and presentation were comprehensible and accessible.

Graphics: Assessing the visual appeal and clarity of images and diagrams in the guide.

Usability: Measuring the practicality and engagement level of the guide in fostering student creativity and interest.

Each aspect was rated on a five-point Likert scale: "Very Good" (5), "Good" (4), "Fair" (3), "Poor" (2), and "Very Poor" (1). Data from the questionnaires were converted into interval scores for analysis using a five-point scale conversion table (Saifuddin Azwar, 1996).

Data Analysis

The collected data were analyzed by converting scores into intervals, categorized into five levels: Very Good (A), Good (B), Fair (C), Poor (D), and Very Poor (E). Table 1 illustrates the score conversion methodology, while Table 2 presents the categorized results for each assessment aspect.

Table 1. Five-scale score conversion

Score interval	Value	Category
$X > xi + 1{,}5\ SBi$	A	Very Good
$xi + 0{,}5\ SBi < X \leq xi + 1{,}5\ Sbi$	B	Good
$xi - 0{,}5\ SBi < X \leq xi + 0{,}5\ Sbi$	C	Fair
$xi - 1{,}5\ SBi < X \leq xi - 0{,}5\ Sbi$	D	Poor
$X \leq xi - 1{,}5\ Sbi$	E	Very Poor

For example, the clarity aspect was rated "Very Good" for scores exceeding 12.0, with subsequent intervals categorized as Good, Fair, Poor, and Very Poor. Similarly, the graphics aspect received "Very Good" ratings for scores above 8.0, and the usability aspect was rated "Very Good" for scores above 20.0. These results validated the practicum guide's high feasibility and effectiveness in achieving its educational objectives (Sharma et al., 2019).

Table 2. Conversion results of a five-scale score for each assessment aspect

Assessment aspect	Interval	Value	Category
Clarity	X > 12,0	A	Very Good
	10,0 < X ≤ 12,0	B	Good
	8,0 < X ≤ 10,0	C	Fair
	6,0 < X ≤ 8,0	D	Poor
	X ≤ 6,0	E	Very Poor
Graphics	X > 8,0	A	Very Good
	6,6 < X ≤ 8,0	B	Good
	5,4 < X ≤ 6,6	C	Fair
	4,0 < X ≤ 5,4	D	Poor
	X ≤ 4,0	E	Very Poor
Usability	X > 20,0	A	Very Good
	16,6 < X ≤ 20,0	B	Good
	13,3< X ≤ 16,6	C	Fair
	10,0 < X ≤ 13,3	D	Poor
	X ≤ 10,0	E	Very Poor

RESULTS AND DISCUSSION

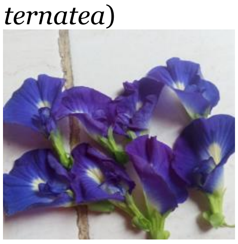
Results

Identification of Sasambo Plants for Natural Dyes Sources

The initial identification of Sasambo plants suitable as sources of natural dyes focused on plants with vibrant and distinct colors. Various parts of these plants, including flowers, leaves, seeds, and fruits, were examined. Laboratory testing and field observations revealed that ten plants demonstrated potential as sources of natural dyes. Table 3 summarizes the findings:

Table 3. Results of Natural Dyes Indicator Testing

No	Plant Part	Extract Result	Active Compound(s)
1	Bunga kencana ungu (*Ruellia Simplex*) 	Purple extract 	Anthocyanins
2	Kunyit (*Curcuma longa*) 	Yellow extract 	Curcumin
3	Buah jowet /Jamblang (*Syzygium cumini*)	Purple extract	Anthocyanins

			
4	Biji Pinang (*Areca catechu*) 	Brown-red extract 	Flavonoids and Tannins
5	Sawo mentega (*Pouteria campechiana*) 	Yellow extract 	Carotenoids
6	Bunga Telang (*Clitoria ternatea*) 	Blue extract 	Anthocyanins
7	Biji Lebui (*Cajanus cajan*) 	Black extract 	Polyphenols, Anthocyanins, Flavonoids
8	Buah Kemuning (*Murraya paniculata*) 	Orange extract 	Semi-alpha Carotene
9	Daun Pandan (*Pandanus amaryllifolius*) 	Green extract 	Chlorophyll
10	Daun Ubi jalar (*Ipomoea batatas*)	Green extract	Chlorophyll

The results highlight the diverse bioactive compounds present in these plants, such as anthocyanins, curcumin, chlorophyll, flavonoids and carotenoids. These compounds not only serve as effective natural dyes but also offer additional functional benefits, such as antioxidant properties.

Validation of the Practicum Guide

The developed practicum guide was validated by experts and evaluated by two chemistry lecturers using a structured questionnaire. The questionnaire assessed three key aspects: clarity, graphics, and usability. Table 4 presents the average scores obtained:

Table 4: Average Validation Scores from Experts and Lecturers

Assessment Aspect	Expert Average	Lecturer Average	Overall Average
Clarity	12.0	12.8	12.40
Graphics	7.0	7.5	7.25
Usability	22.0	22.6	22.30

The results were further analyzed using the five-scale conversion in Table 2. Based on this analysis, the feasibility of practicum guide is shown in Table 5:

Table 5. Feasibility Assessment of the Practicum Guide

Assessment Aspect	Average Score	Interval	Category
Clarity	12.40	$X > 12.0$	Very Good
Graphics	7.25	$6.6 < X \leq 8.0$	Good
Usability	22.30	$X > 20.0$	Very Good

Based on the results of expert validation and lecturer assessments, it can be concluded that the assessments aspects in the form of clarity is included in the "Very Good" category, indicating that the content, language, and structure are easy to understand. The graphic aspect is categorized as "Good," reflecting adequate visual appeal and clear illustrations. The usability aspect is rated as "Very Good," demonstrating the guide's effectiveness in engaging students and facilitating creative and enjoyable practical sessions.

Overall Assessment

The validation results indicate that the developed practicum guide is feasible for use in educational settings. The high ratings in clarity and usability highlight the guide's potential to support students learning while fostering awareness of sustainable practices. The integration of natural dyes derived from Sasambo plants not only enriches chemistry education but also promotes environmental conservation and the preservation of local cultural knowledge.

Discussion

Bioactive Compounds and Functional Properties

The natural dyes extracted from Sasambo plants demonstrated diverse bioactive compounds with significant functional properties. For example, *Ruellia simplex* contains anthocyanins, which provide a stable purple color and exhibit strong antioxidant properties, making it a suitable candidate for eco-friendly dyeing (Sudarmin et al., 2020; Aggarwal, 2021). Similarly, *Curcuma longa* produces a bright yellow dye from curcumin, a compound with anti-inflammatory and antimicrobial properties that is also highly valued in the pharmaceutical industry (Aggarwal & Shukla, 2020). The findings confirm that anthocyanins, flavonoids, and chlorophyll, present in various Sasambo plants, contribute not only to vibrant colors but also to additional health benefits, enhancing their applicability in textiles and other industries (Yang et al., 2021).

The potential of *Syzygium cumini* as a natural dye lies in its anthocyanin content, which provides a deep purple hue suitable for textile and food applications. Other plants, such as *Areca catechu* and *Pouteria campechiana*, offer durable and pH-stable colors, indicating their flexibility for diverse practical applications (Sharma et al., 2019). The dye extracted from *Areca catechu* contains flavonoids and tannins, providing a long-lasting golden-brown color with additional antibacterial properties. The flavonoids and tannins in *Areca catechu* also serve as agents to prevent infections and enhance the immune system (Yernisa, 2013).

Pouteria campechiana produces a yellow-orange color derived from its carotenoid content, which remains stable across various pH levels, making it versatile for a wide range of practical applications. The carotenoid-rich *Pouteria campechiana* demonstrates significant potential as a nutritional source for eye health and the prevention of degenerative diseases (Juniarti, 2016). *Clitoria ternatea* is rich in anthocyanins, producing a bright blue color that can change to purple or red depending on the pH environment. Similarly, *Ruellia simplex*, *Syzygium cumini*, and *Clitoria ternatea* have been found to contain anthocyanins, compounds known for their high antioxidant properties. These compounds are essential for protecting the body from damage caused by free radicals and can also serve as natural colorants for food products (Rifqi, 2021). Meanwhile, *Cajanus cajan* contains polyphenols, anthocyanins, and flavonoids, producing a dark purple color with broad potential applications in textiles and food.

Murraya paniculata generates a bright orange color from its semi-alpha carotene content, which remains stable at high temperatures, making it ideal for industrial applications. In addition, *Murraya paniculata* offers antioxidant benefits from its semi-alpha carotene content, helping to prevent cell damage caused by oxidation. *Pandanus amaryllifolius* and *Ipomoea batatas* both produce natural green colors from chlorophyll, along with significant antioxidant properties, making them not only suitable as colorants but also beneficial for health. In samples of *Pandanus amaryllifolius* and *Ipomoea batatas*, chlorophyll was found to possess detoxifying properties and support cell regeneration. Chlorophyll also holds potential for pharmaceutical applications as an active ingredient in health supplements (Putri & Astuti, 2022).

Practical Application in Education and Industry

The integration of natural dyes into chemistry education through the developed practicum guide provides students with hands-on experience in sustainable practices. This aligns with global trends in green technology education, emphasizing the importance of renewable resources and eco-friendly practices (Shamsheer et al., 2021). By using local materials, students gain insights into the environmental impacts of synthetic chemicals and the benefits of natural alternatives, fostering critical and creative thinking (Delaney et al., 2022). From an industrial perspective, natural dyes offer ecological and economic advantages over synthetic dyes. Unlike synthetic alternatives, which often contain hazardous chemicals, natural dyes minimize environmental pollution and can support local economies by utilizing indigenous resources (R, 2023). For instance, the cultivation and processing of Sasambo plants for dyes could generate additional income for local farmers and small-scale industries, promoting sustainable economic development (Aggarwal, 2021).

Challenges and Solutions in Natural Dye Applications

Despite their advantages, natural dyes face several challenges in practical and industrial applications. Variability in dye yields, color stability, and reproducibility are notable concerns (Yang et al., 2021). Climatic conditions, extraction methods, and mordants significantly influence the final product’s quality and durability (Shamsheer et al., 2021). For example, anthocyanins are pH-sensitive, which may affect their stability during the dyeing process. To address these challenges, environmentally friendly mordants such as alum or biomordants derived from plant-based materials can be utilized to improve dye fixation while maintaining eco-friendly standards (Yang et al., 2021). Advances in extraction techniques, such as UV-Vis spectroscopy, can also enhance accuracy and reproducibility, ensuring consistent quality across applications (Sharma et al., 2019). These approaches could pave the way for scaling up natural dye production and optimizing their use in education and industry.

Contribution to Environmental Sustainability and Cultural Preservation

The use of Sasambo plants as natural dye sources significantly contributes to environmental sustainability by reducing reliance on synthetic chemicals. This approach minimizes hazardous waste and promotes the utilization of renewable plant resources (Sudarmin et al., 2020). Additionally, the integration of local plants into educational practices fosters a deeper appreciation of biodiversity and cultural heritage among students. By learning about traditional knowledge and its applications in modern contexts, students develop a greater sense of responsibility toward preserving their natural and cultural environments (R, 2023). The practicum guide’s emphasis on ethnoscience aligns with the broader objective of linking scientific education with cultural and environmental awareness. By exploring the intersection of traditional knowledge and modern methodologies, the guide encourages students to adopt sustainable practices that benefit both society and the environment (Delaney et al., 2022).

Implications and Future Research

The findings underline the feasibility of integrating natural dyes into educational and industrial settings. However, further research is needed to optimize extraction techniques and explore the potential applications of bioactive compounds beyond dyeing, such as in cosmetics or pharmaceuticals (Aggarwal & Shukla, 2020). Future studies should also address the scalability of natural dye production and its long-term economic and ecological impacts. By advancing the understanding and application of natural dyes, this research contributes to global efforts in promoting sustainability and reducing environmental footprints. The integration of local wisdom and modern science in the developed practicum guide represents a significant step toward achieving these goals, fostering innovation and sustainability in education and industry alike.

CONCLUSION

The research concludes that the developed practicum guidelines for natural dyes based on Sasambo indigenous plants are highly effective as educational tools. These guidelines integrate traditional knowledge with scientific methods, fostering students' understanding of sustainable practices and promoting the use of eco-friendly materials. Expert validation highlighted their clarity, graphical appeal, and usability, ensuring engaging and meaningful learning experiences. Moreover, the practical application of natural dyes not only aligns with global sustainability goals but also underscores the importance of preserving local biodiversity and cultural heritage. These efforts contribute to environmental conservation and sustainable economic development by utilizing renewable local resources.

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