

QR Code-Based Ecoprint Catalog Digitalization as a Strategic Innovation for Sustainable MSME Development at Tembindigo

Digitalización del Catálogo de Ecoprint Basado en Código QR como Innovación Estratégica para el Desarrollo Sostenible de las MIPYMES en Tembindigo

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ABSTRACT

Introduction: new eco-friendly creative industries focus on sustainable innovations such as ecoprinting which transfers natural motifs from plants onto fabrics. However, many Micro, Small, and Medium Enterprises (MSMEs) still grapple with production consistency issues stemming from inadequate botanical knowledge. Therefore, this study focused on developing a digital ecoprint catalogue based on QR codes at Tembindigo MSME in Yogyakarta. The objectives included documenting the characteristics of local plants to enhance ecoprint training sessions and foster sustainability-oriented developmental growth within MSMEs.

Method: the study used a Participatory Action Research (PAR) design that included seven members from Tembindigo MSME and 25 participants of the training. Some of the key steps were entitled local plant asset mapping, collecting leaves alongside their motifs, and combining that with the digital catalogue to embed QR codes. As for user satisfaction and the effectiveness of digitalisation, both variables were analysed through Likert-scaled questionnaires and quantitative analysis alongside qualitative word cloud feedback.

Results: the results showed that 85 % of the documented plants formed distinct and consistent motifs. Users reported overall satisfaction with the platform (mean score above 4,5/5) and praised its accessibility, information clarity, and effectiveness in treatment-shared guidance. Furthermore, the QR-based system minimized trial-and-error processes and significantly bolstered self-paced learning in training sessions. It also added to Tembindigo's branding and experience value offered to visitors.

Conclusion: the overall learning and motif consistency were notably enhanced through the use of the QR-based ecoprint catalogue, therefore, providing an innovative and MSME-friendly solution. It integrates traditional crafts and digital technologies, strengthens the branding of MSMEs, and fosters sustainable eco-friendly entrepreneurship. This model can be utilized by ecoprint-based MSMEs aiming to enhance training, quality, and market outreach.

Keywords: QR Codes; Ecoprint; Digitalization; Catalog; Innovation; Motifs.

RESUMEN

Introducción: las nuevas industrias creativas ecológicas se centran en innovaciones sostenibles como el *ecoprinting*, una técnica que transfiere motivos naturales de plantas a telas. Sin embargo, muchas micro, pequeñas y medianas empresas (MiPyMEs) aún enfrentan problemas de consistencia en la producción debido al conocimiento botánico insuficiente. Por ello, este estudio se enfocó en desarrollar un catálogo digital de ecoprint basado en códigos QR en la MiPyME Tembindigo en Yogyakarta. Los objetivos incluyeron documentar las características de las plantas locales para mejorar las sesiones de capacitación en ecoprint y promover un crecimiento orientado a la sostenibilidad dentro de las MiPyMEs.

Método: el estudio utilizó un diseño de Investigación-Acción Participativa (IAP), que involucró a siete miembros de la MiPyME Tembindigo y a 25 participantes de la formación. Las etapas clave incluyeron el mapeo de los activos vegetales locales, la recolección de hojas junto con sus respectivos motivos, y su integración en un catálogo digital vinculado a códigos QR. La satisfacción del usuario y la efectividad de la digitalización se evaluaron mediante cuestionarios con escala Likert y un análisis cuantitativo complementado con comentarios cualitativos representados

en nubes de palabras.

Resultados: los resultados mostraron que el 85 % de las plantas documentadas generaron motivos nítidos y consistentes. Los usuarios expresaron una alta satisfacción general con la plataforma (promedio superior a 4,5/5) y elogiaron su accesibilidad, claridad de la información y eficacia en la orientación sobre los tratamientos. Además, el sistema basado en códigos QR minimizó los procesos de ensayo y error, y fortaleció significativamente el aprendizaje autónomo durante las sesiones de capacitación. También contribuyó al fortalecimiento de la marca Tembindigo y al valor experiencial ofrecido a los visitantes.

Conclusión: el aprendizaje y la consistencia en los motivos se mejoraron notablemente mediante el uso del catálogo de ecoprint basado en códigos QR, proporcionando así una solución innovadora y accesible para las MiPyMEs. Este modelo integra artesanías tradicionales con tecnologías digitales, fortalece el posicionamiento de marca de las MiPyMEs y promueve el emprendimiento sostenible y ecológico. Puede ser adoptado por otras MiPyMEs basadas en ecoprint que busquen mejorar la formación, la calidad del producto y el alcance comercial.

Palabras clave: Códigos QR; Ecoprint; Digitalización; Catálogo; Innovación; Motivos.

INTRODUCTION

The creative industry based on local wisdom is experiencing a shift in orientation in line with the growing awareness of sustainability and eco-friendly products.⁽¹⁾ One notable innovation emerging within the MSME sector is the ecoprint technique, which involves transferring natural patterns onto fabric using pigments extracted from leaves, flowers, and other plant parts.⁽²⁾ This technique is advantageous as it harnesses locally abundant resources, requires relatively low production costs, and yields unique products with a strong local identity. Despite these benefits, the ecoprint process remains highly dependent on a comprehensive understanding of plant characteristics and appropriate treatment methods. This dependency often becomes a key source of failure, particularly among novice artisans.⁽³⁾ Systematic efforts are lacking to document and digitize botanical knowledge relevant to ecoprinting. Digitalizing information about plant types and ecoprinting procedures can reduce trial-and-error practices, increase efficiency, and improve production outcomes.⁽⁴⁾ Such an approach is essential to support the sustainability of MSMEs and reinforce the growth of creative industries rooted in cultural heritage and environmental responsibility.

Tembindigo MSME in Yogyakarta is one of the leading ecoprint enterprises that has successfully utilized local natural resources by cultivating various uniquely characterized plants in a well-managed system. This MSME has developed a business model integrating production, education, and a product showroom, working synergistically to support economic empowerment and environmental conservation.⁽⁵⁾ The educational approach has become a key strategy to strengthen branding while addressing the competitive challenges among ecoprint MSME players. Nevertheless, a major challenge (especially for emerging MSMEs) is the high failure rate in producing sharp motifs and consistent colours due to mismatches between treatment techniques and the specific characteristics of each leaf type.^(6,7) The lack of well-documented technical guidelines accessible to practitioners and training participants further exacerbates this issue. Therefore, innovations such as the digitalization of botanical knowledge and the development of standardized modules based on research in natural dye extraction and fixation are urgently needed to improve production success.^(8,9) These efforts help reduce repeated mistakes and enhance the competitiveness of ecoprint products as part of the growing sustainable creative industry movement.⁽¹⁰⁾

The success of the ecoprinting technique is influenced by various factors, including leaf type, moisture content, tannin levels, surface texture, and the application methods used, such as pounding, steaming, or boiling.^(11,12,13) Leaves with high tannin content, such as teak (*Tectona grandis*), generally produce sharper colours and motifs due to their reactive chemical properties.⁽¹⁴⁾ However, the literature providing detailed insights into plant characteristics and specific treatment techniques for optimal pigment extraction remains limited. Most experimental practices in the field are highly personal and poorly documented, making replication and standardization in production difficult.⁽¹⁵⁾ As a result, many MSMEs still lack cataloguing systems that can predict motif outcomes based on specific leaf materials, leaving the production process reliant on individual intuition and experience.⁽¹⁶⁾ This inconsistency also hinders the exploration of new motif combinations from diverse leaf types due to the absence of visual references and supporting data.⁽¹⁷⁾ Therefore, a more systematic approach is needed, particularly through developing a database of local plants, their morphological characteristics, and the resulting motif outcomes. Such a reference system would enhance the quality, consistency, and innovation of ecoprint practices.⁽¹⁸⁾

Tembindigo MSME has introduced a strategic innovation by digitally transforming its empirical knowledge into a QR-code ecoprint catalog. This catalog systematically documents the outcomes of experiments on various local plant species used in ecoprinting and is accessible to visitors and training participants.⁽¹⁹⁾ Doing so not only enhances the educational value and strengthens the MSME's branding but also functions as an interactive marketing tool that enriches the customer experience through direct access to plant characteristics and motif results.^(20,21) Digitalization offers a practical solution to reduce dependence on trial-and-error methods and enables practitioners to understand the interplay between leaf structure, tannin content, and optimal processing techniques.^(22,23) Few initiatives have effectively integrated ecoprint practice, botanical data, and digital technology into a single, user-friendly platform. Through developing a structured database, Tembindigo supports the consistent reproduction of high-quality motifs and reinforces the sustainability of creative enterprises grounded in local biodiversity.^(24,25) This initiative demonstrates that embedding

digital technology within traditional crafts can drive innovation, expand market reach, and raise environmental awareness across MSME communities.^(3,26)

The issues were addressed through a Community Service (PkM) initiative to develop a digital knowledge system for ecoprint motifs based on local plant resources. This initiative sought to reduce production failures and enhance training effectiveness at Tembindigo MSME. The activities included exploring plant characteristics, documenting experimental outcomes, and compiling a QR code-based digital catalog that is easily accessible and user-friendly for visitors and other MSME practitioners. The resulting digital innovation is a replicable model for other ecoprint MSMEs in Indonesia, particularly those focused on sustainability and locally rooted creative economies.

METHOD

The Community Service (PkM) initiative adopted the Participatory Action Research (PAR) approach as its primary method. This approach was chosen to promote the active involvement of the Tembindigo MSME in designing and developing a sustainable ecoprint business unit based on real needs and local experience.⁽²⁷⁾ PAR emphasizes collaboration and participation, positioning the community partner not merely as an object of intervention but as a central agent of change. The strategies formulated became more contextually relevant and practically applicable through iterative cycles of reflection, action, and joint evaluation. Previous studies have shown that the PAR approach is effective in facilitating the development of plant catalogs, digitalizing production processes, and implementing QR code-based educational tools, which strengthen community ownership of knowledge.^(28,29) By engaging MSME actors directly in every stage, this initiative also enhanced their adaptive capacity to change and contributed to the program's long-term sustainability.

The implementation of this initiative involved seven internal members of the Tembindigo MSME, including the owner and workers, who served as key sources of knowledge, experience, and decision-making in the plant experimentation process. In addition, twenty-five visitors and ecoprint training participants were engaged as early users to validate the information and assess user satisfaction with the developed digital platform. As illustrated in figure 1, the activity followed several stages: starting with an asset and potential analysis of the MSME (particularly its motif plant garden), followed by the development of an ecoprint training business unit, the creation and organization of a digital plant database, user validation of experimental results and catalog content, and concluding with an evaluation of the QR Code-based digital catalog's usability and impact.

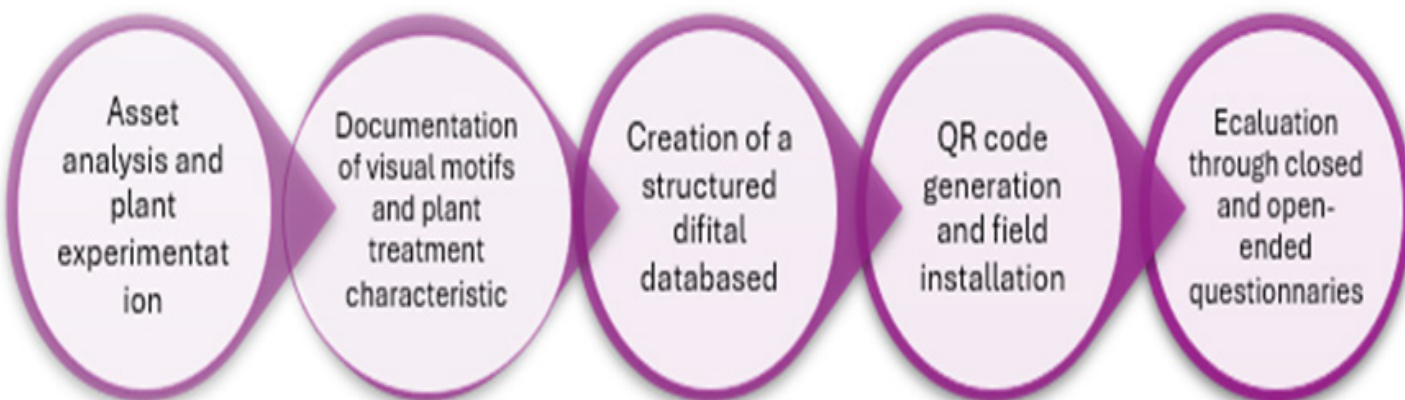


Figure 1. Stages of Creating an Ecoprint Motif Digitalization System

The instruments used in each stage of the activity were designed descriptively. During the asset analysis phase, observation and documentation methods were employed to identify and classify various plant species based on their success in producing clear ecoprint motifs. In the information development phase, data collection included visual documentation, descriptions of plant characteristics, treatment methods, and the final motif outcomes on fabric. Validation was carried out using a closed-ended questionnaire of ten statements measuring user satisfaction and the effectiveness of digitalization. Additionally, an open-ended questionnaire with four questions was administered to visitors, and participants were trained to assess ease of use, clarity of information, and the perceived usefulness of the digital catalog. The final evaluation focused on describing the levels of user satisfaction and the catalog's effectiveness in reducing errors during the ecoprinting process. All collected data were analyzed using descriptive quantitative methods to provide a comprehensive overview of how local empirical knowledge was successfully transformed into accessible and functional digital information.

The questionnaire used to measure user perceptions of the digital ecoprint catalog based on local plants was structured using a 5-point Likert scale. It consisted of two main aspects: user satisfaction and digitalization effectiveness, each comprising five statement items. The detailed questionnaire items are presented in table 1.

Table 1. User Perception After Using Ecoprint Digital Catalog Information		
Parameter	Statement	Scale
User Satisfaction	QR Code is easily accessible and functional	1-5
	Plant information in the catalog is easy to understand	1-5
	Pictures and descriptions of motifs on the fabric are quite clear	1-5
	The catalog helps me understand the ecoprint process	1-5
	I am satisfied with using this digital catalog during training	1-5
Effectiveness of Catalog Digitalization	The catalog helps me choose the right type of plant	1-5
	This digitization reduces errors during the ecoprinting process	1-5
	The platform provides practical guidance on leaf treatment	1-5
	I can compare the results of motifs from several plants	1-5
	This platform is worth using in the next ecoprinting training	1-5
Note: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; and 5 = Strongly Agree		

The results were then categorized based on questionnaire items related to user satisfaction and effectiveness of digitalization. The outcomes were determined by calculating and classifying the mean scores into defined categories. A minimum score in the “Good” or “Effective” category indicated the program’s implementation success.

Table 2. Level of satisfaction and effectiveness based on categorization	
Average Score Range	Category
4,21 – 5,00	Very Good / Very Effective
3,41 – 4,20	Good / Effective
2,61 – 3,40	Fair / Fair Effective
1,81 – 2,60	Less / Less Effective
1,00 – 1,80	Very Poor / Ineffective

Subsequently, users were asked to provide feedback to express their experiences and perceptions while engaging with the digital catalog system. Four open-ended questions were constructed, and the responses were analyzed and categorized using a word cloud visualization to capture key terms and recurring themes. The open-ended questions were as follows:

- In your opinion, what information was most helpful from this digital catalog?
- Are there any plant types or treatment methods that should be added to the catalog? Please explain.
- Did you encounter difficulties using the digital platform or scanning the QR Code? If so, what were they?
- What are your suggestions for making this catalog more useful for future ecoprint training sessions?

RESULTS AND DISCUSSION

Tembindigo MSME possesses highly valuable assets for developing ecoprint practices based on local plant resources. One of its primary strengths lies in a well-managed garden containing various plants used as raw materials for ecoprint motifs. This garden is a production source and an educational tourism attraction that appeals to local and international visitors. Guests can observe, understand, and directly participate in the ecoprinting process. Despite these advantages, a limited understanding of the diverse characteristics and appropriate treatments of leaves often leads to failure in motif formation.^(30,31,32) To address this issue, an innovation was introduced: digitalizing plant information to provide practical education to visitors and training participants. More than 130 plant species have been tested and systematically documented for their potential to produce ecoprint motifs.

The availability of a well-structured ecoprint raw material garden managed by Tembindigo MSME is a strategic asset in developing education-based and sustainability-oriented business innovations. This garden is utilized not only as a production source but also as a direct learning platform that attracts local and international visitors.⁽²⁸⁾ Public ecoprint motif training sessions encourage active participation in the creative process, increasing the likelihood of purchasing products created during these sessions. This approach aligns with the principles of experiential learning, which enhances understanding, emotional engagement, and consumer loyalty toward products rooted in local wisdom.^(29,33) Beyond its educational function, the training activity also serves as an effective promotional strategy to strengthen the brand identity of Tembindigo as an environmentally conscious modern batik producer. By integrating production, training, and marketing within a unified business ecosystem, this MSME demonstrates a sustainable business model responsive to the growing trends of educational tourism and eco-conscious lifestyles.⁽³⁴⁾

Tembindigo MSME has demonstrated innovation by developing an experiential-based training program and cultivating more than 130 plant species as raw materials for ecoprint motifs. This extensive plant diversity is a competitive advantage not commonly found in other ecoprint MSMEs. The wide variety enriches the visual possibilities of motif outcomes and adds deeper aesthetic and philosophical value to the printed results. However, novice training participants often face challenges in producing clear motifs,

primarily due to improper treatment methods not aligned with each leaf type's natural characteristics.⁽³⁵⁾

The development of Tembindigo's business unit is guided by efforts to strengthen brand identity and provide on-site experiential training services. While each ecoprint MSME typically applies distinct techniques and treatments, Tembindigo stands out through its emphasis on hands-on educational experiences. This training program has become a core priority to enhance participants' technical understanding and as a strategic means to attract interest and increase engagement, particularly among international visitors. Training participants are guided through the process, from leaf selection and material preparation to the final motif printing on fabric. This approach has proven effective in enhancing the appeal of Tembindigo's products and has significantly influenced immediate purchase decisions following the training sessions.

The creation and organization of the plant-based digital database were carried out by mapping the characteristics of each leaf type, its specific treatment methods, and the resulting motif outcomes. This information was then compiled into a structured digital plant-based ecoprint catalog. Subsequently, the data were encoded into QR Codes, which were installed on each plant within the ecoprint garden. Visitors can scan these QR Codes using mobile devices to instantly access detailed information about the plant species, recommended treatment techniques, and visual examples of motif outcomes on fabric. This approach has proven practical and educational, providing real-time access to information on-site without additional guides. It also transforms the visitor experience into an interactive and digitized learning journey.

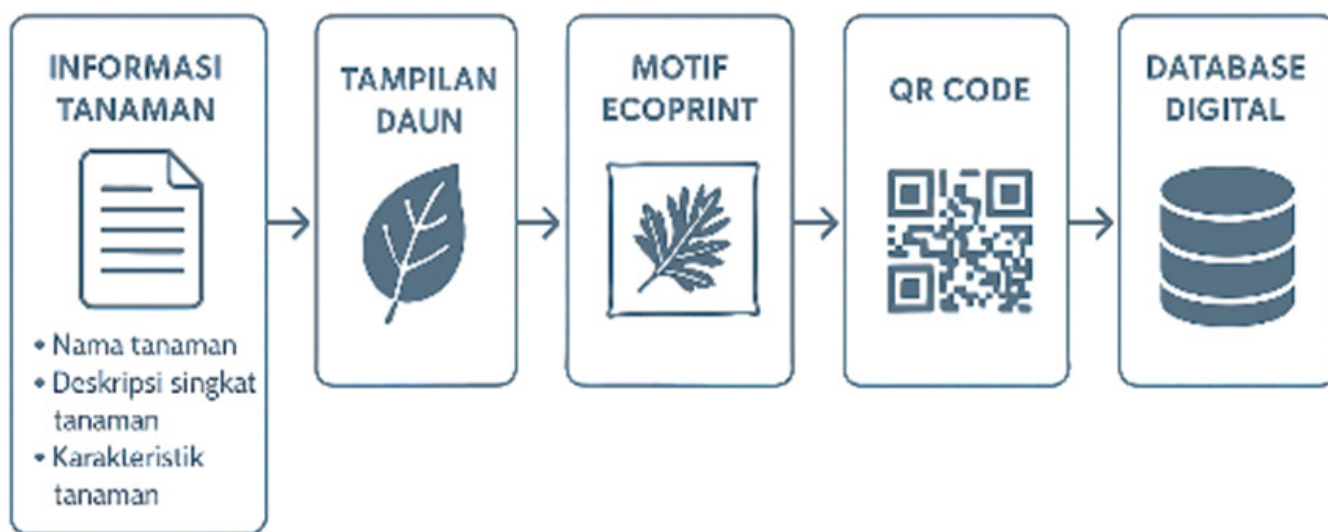


Figure 2. Flow of Development of Leaf Digitalization into Ecoprint Motifs

In response to these challenges, Tembindigo MSME designed the digitalization of plant information as an innovative breakthrough to simplify the learning process. The tested plant data were documented and processed into a digital database, which was then integrated into QR Codes and placed directly on or near the corresponding plants within the garden. By scanning the QR Codes using mobile devices, visitors and training participants can access essential information such as plant names, leaf characteristics, appropriate treatment techniques (pounding, steaming, boiling), and visual examples of the resulting motifs. This digitalization offers fast and accurate access to knowledge, which is particularly beneficial for beginners who require practical guidance during ecoprint experimentation.

The MSME owner and workers, who served as experience-based experts, validated the accuracy of information and treatment methods. The validation process involved cross-checking visual motif data, plant characteristic descriptions, and the applied treatment techniques (figure 3). In addition, repeated simulations were carried out on selected plant species to test the consistency of the results. The review focused on verifying the accuracy of information embedded in the QR Codes, including pigment content, the most effective processing method (steaming, pounding, or boiling), and the dominant colors produced (figure 4). The validation findings revealed that 85 % of the cataloged plant data yielded motif results consistent with re-testing, while the remaining entries were revised to clarify treatment instructions.

User evaluation was conducted with 25 training participants and visitors through closed-ended and open-ended questionnaires (figure 5). The results from the closed-ended questionnaire indicated that users responded positively to the digital catalog's usefulness in guiding the ecoprinting process.

Based on figure 5, participant satisfaction with the digitalization initiative is illustrated across several key aspects. For the aspect *"the plant information in the catalog is easy to understand"*, the average score was 4,56, categorized as *very good*. Participants noted that the descriptions of plant characteristics, treatment methods, and motif outcomes were presented in clear and accessible language. This clarity is critical given the diverse backgrounds of the users, ranging from beginners to experienced ecoprint practitioners. The information was structured bilingually (Indonesian–English), enabling quicker comprehension, especially for international visitors. Tembindigo MSME has successfully simplified complex botanical knowledge into inclusive educational content.



Figure 3. QR Code Display and Plant Motif Information



Figure 4. QR Code Installation and Information Display Results

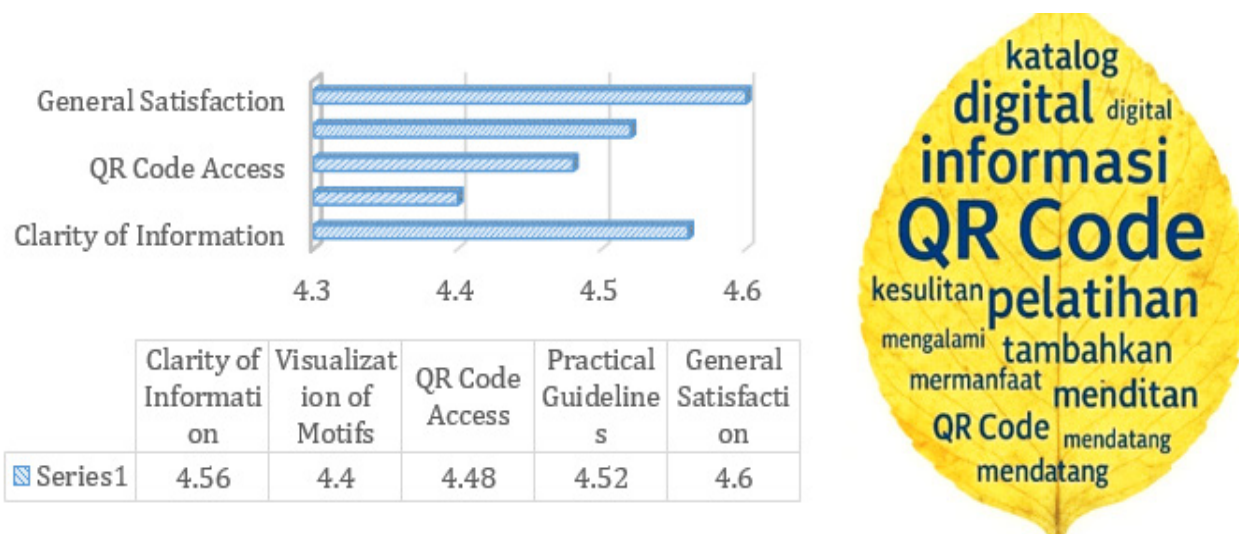


Figure 5. Results of User Satisfaction Evaluation and Effectiveness of QR Code Digitalization

Regarding the aspect “*images and descriptions of motifs on fabric are clear*,” the average score was 4,40, falling into the *good* category. Clarifying visual motifs is crucial, as participants must compare their expectations with actual outcomes during practice. The images presented in the catalog were considered representative of real results. However, some users suggested improvements in lighting or variations in the fabric background to make the motifs appear sharper. Tembindigo has documented motif outcomes from experiments with over 130 plant species, a distinctive strength.

For the aspect “*QR Codes are easily accessible and functional*,” an average score of 4,48 was recorded, indicating *very good*. The accessibility of QR Codes in the garden setting was one of the most appreciated features. Participants could scan the codes to access complete information without manual note-taking, facilitating mobility during training sessions. The QR Codes are directly linked to the catalog database, representing an innovative approach not yet implemented by other ecoprint MSMEs. Some participants recommended adding physical markers to prevent the QR Codes from being obscured by leaves or damaged by rain.

For the “*The catalog helps me understand the ecoprinting process*”, an average score of 4,52 was recorded, which falls into the *very good* category. The digital catalog provides information about the plants and offers contextual practical guidance. Participants could identify the appropriate treatment methods (such as pounding, steaming, or boiling) for each specific plant. This directly contributed to reduced failure rates during hands-on practice, which was previously common due to incorrect leaf treatment. Tembindigo MSME has effectively established an educational ecosystem that connects the plant garden directly to the training process.

Finally, for the aspect “*I am satisfied with using this digital catalog during training*”, the highest average score of 4,60 was achieved, also in the *very good* category. This indicates that users experienced the most significant level of satisfaction from the overall interactive and educational value of the catalog. The responsive QR Codes, informative content, and direct relevance to practical ecoprinting made the catalog an essential tool during training. Participants felt actively engaged in a learning process that was hands-on, current, and experience-based rather than merely theoretical.

Based on figure 5, several key terms are illustrated in the word cloud analysis. The most frequently mentioned and helpful elements of the digital catalog were represented by the terms “information,” “QR Code,” “digital,” and “plant.” The words “information” and “QR Code” dominated participant feedback, indicating that users greatly benefited from easily accessible QR Codes, particularly in recognizing plant species, their characteristics, and the resulting motifs. The QR Code was perceived as a visual bridge between theory and hands-on practice. Regarding plant types and treatments, the words “add,” “plant,” and “treatment” appeared frequently, reflecting participants’ interest in expanding the catalog to include more plant species, especially wild or locally unique plants not yet commonly used. The word “leaf” in the word cloud reflects biodiversity as a central theme, suggesting that the catalog should be more inclusive of various species to support broader experimentation.

Challenges related to using the digital platform or QR Code were expressed with terms like “difficulty” and “experience,” indicating that while a few participants reported technical issues (such as limited internet signal or difficulty scanning QR Codes under low lighting), the overall feedback remained positive. The prominence of the “QR Code” still indicated its general ease of use, with only minor technical adjustments needed. Participant suggestions were captured through words such as “training,” “future,” and “benefit,” showing that the catalog is considered highly promising for future training programs. The visual representation of leaves in the word cloud further underscores the continuity of learning derived from structured natural experiences. The open-ended responses demonstrate that the digitalization of ecoprint motif information carries philosophical and educational value. Innovation offers several key advantages: (1) it represents the primary source of ecoprint motifs; (2) it symbolizes life, growth, and the transformation of natural knowledge into digital form and; (3) it reflects the diversity of each plant species, which must be understood through experimentation and visual reference.

The final evaluation of the digital catalog usage revealed that participants were highly satisfied with the learning experience supported by informative yet straightforward technology. The QR Codes placed on each plant allowed users to engage in independent and contextual learning without disrupting the training flow. This approach significantly enhanced participants’ motivation to continue experimenting beyond the formal training sessions.^(36,37) This method made the training process more effective, the learning experience more structured, and the overall appeal of eco print products more sustained. Consequently, Tembindigo MSME is well-positioned to sustain and develop its ecoprint offerings sustainably.

CONCLUSIONS

This community engagement program successfully achieved its objective of developing a QR code-based digital plant ecoprint catalogue that reduces production failure and strengthens training effectiveness at Tembindigo MSME. The participatory development approach enabled active involvement from local actors, resulting in a well-structured database of over 130 plants, complete with treatment methods and motif outcomes. Evaluation results showed high user satisfaction (mean scores above 4,5) and strong digitalization effectiveness, confirming that the catalogue improved understanding, reduced trial-and-error, and enhanced training quality. The QR-based catalogue provides several advantages: it allows real-time access to plant information in the field, facilitates independent learning, and supports visual comparison of motif outcomes. Integrating educational and interactive elements directly in the ecoprint garden creates a unique experiential learning environment. This improves participant engagement and encourages immediate product purchases following training sessions, effectively linking education with market opportunities. The findings indicate that other ecoprint MSMEs across Indonesia can replicate and adapt this innovation. By combining plant experimentation, structured documentation, and digital tools, MSMEs can enhance product quality while opening new business models through ecoprint training services. The digital catalogue is a powerful medium to strengthen branding, promote local biodiversity, and expand sustainable entrepreneurship rooted in traditional crafts.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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