

Development of Ecoprinting-Based Student Worksheets to Foster Sustainability Awareness among Fifth Graders

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Abstract

This study aimed to develop and evaluate the feasibility and effectiveness of an ecoprinting-based Student Worksheet for Phase C Integrated Science and Social Studies (IPAS) on *Environmental Issues Threatening Life* to foster fifth-grade students' sustainability awareness. Sustainability awareness was examined through three domains: cognitive, affective, and psychomotor, representing sustainability-related knowledge, attitudes, and responsible actions. The study employed a Design-Based Research (DBR) approach based on Reeves, comprising four phases: problem identification and analysis; prototype development; iterative testing and refinement; and reflection. Participants were 31 fifth-grade students at SDN Sindanggalih IV, Garut Regency, Indonesia. Data were collected through expert validation, essay tests (pretest–posttest), questionnaires, and observations. The results showed that the Student Worksheet achieved a validity score of 99.66%, indicating very high validity and feasibility. The mean cognitive score increased from 29.03% in the pretest to 91.77% in the posttest, with an N-Gain of 89.72%, categorized as high. The affective score reached 68.50%, categorized as very good, while the psychomotor score reached 86.64%, categorized as high. These findings indicate that the ecoprinting-based Student Worksheet is valid, feasible, and effective in fostering students' sustainability awareness.

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INTRODUCTION

Education plays a strategic role in preparing elementary school students to understand and respond to sustainability challenges. This is particularly relevant for fifth-grade students, who encounter environmental and social issues through their everyday experiences and learning activities. At this stage, students are increasingly able to connect concrete experiences with broader relationships, consider cause-and-effect relationships, recognize different perspectives, and understand how human activities influence environmental and community conditions. These developmental characteristics provide an appropriate foundation for introducing the

interconnected environmental, social, and economic dimensions of sustainability through contextual learning.

Education for Sustainable Development (ESD) has therefore emerged as an educational approach that integrates environmental, social, and economic dimensions into the learning process. UNESCO (2020) states that ESD aims to develop learners' knowledge, skills, values, and behaviors to enable them to make responsible decisions that support sustainable development. This perspective is consistent with Mochizuki and Bryan (2015), who argue that ESD represents a transformative educational approach that prepares learners to respond to sustainable development challenges through transformative learning. Furthermore, Rieckmann (2018) emphasizes that ESD should foster sustainability competencies, including systems thinking, anticipatory thinking, normative competence, collaborative competence, and problem-solving competence, which enable learners to understand and respond to complex sustainability challenges (see also Wiek et al., 2011). Within this broader framework, sustainability consciousness refers more specifically to how individuals understand, value, and act upon sustainability issues. Gericke et al. (2019) conceptualize sustainability consciousness through three interrelated components: knowingness, attitudes, and behavior across the environmental, social, and economic dimensions of sustainability. Thus, sustainability awareness should not be understood merely as environmental awareness, but as an integrated awareness involving knowledge, attitudes, and actions concerning environmental protection, social well-being, and responsible resource use. ESD implementation also serves as a key strategy for achieving the Sustainable Development Goals (SDGs) established by the United Nations. The United Nations Sustainable Development Goals Report highlights that Quality Education (Goal 4) and Responsible Consumption and Production (Goal 12) are mutually reinforcing goals that contribute to sustainable development (United Nations, 2020; Kioupi & Voulvoulis, 2019). In the elementary school context, integrating ESD into Integrated Science and Social Studies (IPAS) is highly relevant because its learning content is closely related to environmental and social phenomena encountered in students' daily lives. Kalsoom and Khanam (2017) argue that the successful implementation of ESD largely depends on teachers' ability to integrate sustainability issues into classroom instruction (see also Scharenberg et al., 2021). Moreover, Andriansyah et al. (2025) emphasize that sustainability awareness provides an important foundation for developing more sustainable attitudes and behaviors. Therefore, IPAS learning provides an appropriate context for fostering fifth-grade students' sustainability awareness through meaningful learning experiences that connect knowledge, attitudes, and responsible actions.

The effectiveness of ESD implementation is strongly influenced by learning strategies that provide active and contextual learning experiences. Riess et al. (2022) state that student-centered learning is more effective in developing sustainability competencies than instruction that merely focuses on content delivery (see also Boeve-de Pauw et al., 2015). In relation to the knowingness, attitudes, and behavior components of sustainability consciousness proposed by Gericke et al. (2019), learning experiences should provide opportunities for students not only to acquire sustainability-related knowledge but also to develop positive attitudes and demonstrate responsible actions. Ardoin et al. (2020) explain that learning experiences connecting students with real-world environmental issues enhance both conceptual understanding and environmental concern. These findings are supported by Brundiens et al. (2021), who reported that experiential

learning contributes significantly to the development of sustainability-related knowledge, attitudes, and behaviors. Lozano et al. (2017) further argue that successful sustainability education requires the integration of curriculum, instructional strategies, and learning materials that actively engage students in the learning process. In Indonesia, Wilujeng et al. (2019) reported that ESD-oriented student worksheets significantly improve students' environmental literacy. These findings indicate that the successful implementation of ESD depends not only on curriculum design (Mahaswa et al., 2024) but also on the quality of instructional materials and learning experiences that enable students to develop sustainability-related knowledge, attitudes, and responsible actions.

A preliminary study was conducted at SDN Sindanggalih IV, Garut Regency, involving one Grade V teacher, classroom observations, interviews, and document analysis. The documents examined included the teacher and student source books, learning outcomes, Learning Objectives, curriculum documents, previous relevant studies, and students' previous learning outcomes. The preliminary analysis focused initially on the cognitive dimension, particularly students' understanding of knowledge related to environmental problems, because knowledge provides an initial foundation for developing attitudes and responsible actions toward sustainability. The findings indicated that the teacher primarily relied on the existing teacher and student source books and had not yet independently developed Student Worksheets (LKPD) that explicitly integrated sustainability issues or local environmental contexts. Consequently, students had limited learning opportunities to develop sustainability-related knowledge through contextual experiences, and sustainability awareness had not yet been explicitly facilitated in classroom learning. The preliminary interview and observations also indicated that students were familiar with batik as part of their local environment and had seen or experienced environmental impacts associated with batik production. At the same time, batik production has broader social and economic significance in the Garut community, functioning as a local cultural identity, involving community-based production activities, and providing a source of income for local people. Therefore, batik production was positioned not merely as a source of environmental pollution but as an authentic IPAS learning context through which students could examine the relationships among production activities, resource use, environmental quality, community well-being, cultural identity, and local economic activities. This context is closely related to the Phase C IPAS topic *Environmental Issues Threatening Life*, enabling students to investigate the potential environmental impacts of synthetic dye waste (Zakaria et al., 2023) while recognizing the social and economic importance of batik production. The findings of the preliminary study indicate a gap between the sustainability-oriented objectives of IPAS learning and their implementation in classroom practice, highlighting the need for innovative instructional materials that connect scientific knowledge, local environmental issues, community contexts, and sustainability considerations through meaningful learning experiences.

One potential solution to bridge this gap is the development of ecoprinting-based Student Worksheets. In this study, ecoprinting refers to a textile printing activity that uses plant materials, such as leaves, flowers, stems, and roots, to create patterns on fabric through direct contact and mechanical pounding (Flint, 2008). However, ecoprinting is not assumed to be inherently sustainable; its sustainability depends on how natural resources, materials, water, and supporting substances are used and managed. Therefore, the learning activity in this study encourages

students to consider the responsible use of plant materials, avoid excessive harvesting, use water appropriately, and use alum (tawas) in controlled amounts. The activity uses linen fabric, a wooden mallet, a basin, water, alum, newspaper or plastic, and various plant materials, allowing students to directly observe how natural resources can be utilized to create a functional textile product. This approach is consistent with the concept of ecopedagogy, which emphasizes contextual learning experiences that develop students' ecological awareness through meaningful interactions with their environment (Supriatna, 2016). Maulida (2021) explains that environmentally oriented activities such as ecoprinting can provide an educational context for introducing the responsible utilization of local biodiversity. Furthermore, Pratiwi et al. (2025) reported that ecoprinting-based learning can enhance environmental awareness, creativity, and students' active engagement in sustainable practices in elementary schools (Universitas Pendidikan Indonesia, 2025). For fifth-grade students, the activity provides opportunities for concrete problem-solving and decision-making, such as selecting and arranging plant materials, while placing plants on fabric, covering them, pounding them with a wooden mallet, removing the plant materials, and preparing the fabric for alum treatment involve fine-motor coordination. The activity can also encourage collaboration through sharing materials, dividing responsibilities, and working together to complete the product. The procedures are conducted under teacher supervision using age-appropriate tools and materials, particularly during the use of the wooden mallet and alum. Thus, the ecoprinting-based Student Worksheet is not presented as automatically sustainable, but as a contextual learning medium through which students can examine responsible resource use, environmental impacts, cooperation, and more responsible production practices. Through this activity, students can connect IPAS concepts with concrete experiences while developing sustainability-related knowledge, attitudes, and responsible actions.

Previous studies have primarily focused on ESD implementation, Student Worksheet development, or environmental literacy enhancement as separate research topics. Studies investigating ecoprinting in education have generally emphasized students' creativity and practical skills, whereas research integrating Education for Sustainable Development (ESD), local environmental issues, and sustainability awareness within a single instructional material remains limited. In the present study, the ESD orientation is translated into learning activities that address responsible resource use, environmental protection, community well-being, and responsible production practices, particularly in relation to Sustainable Development Goal (SDG) 4 (Quality Education) and SDG 12 (Responsible Consumption and Production). These orientations are operationalized through activities and assessments that address sustainability-related knowledge, attitudes, and responsible actions, consistent with the sustainability consciousness framework of Gericke et al. (2019). At the cognitive level, students are guided to understand resource limitations, identify environmental impacts, and recognize sustainable solutions; at the affective level, students are encouraged to develop empathy toward nature, personal responsibility, and appreciation of natural materials; and at the psychomotor level, students demonstrate responsible practices through the use of materials, implementation of the ecoprinting procedure, and collaborative activities. Compared with conventional elementary-school worksheets that tend to emphasize conceptual exercises and task completion, the present worksheet introduces a contextual and experiential pedagogical innovation by integrating the local context of Garut batik production and its environmental, social, and economic dimensions with hands-on ecoprinting

activities, reflection, and sustainability-oriented assessment. Furthermore, the use of the Design-Based Research (DBR) approach enables the worksheet to be developed through iterative stages of analysis, design and development, testing, and reflection, with the aim of generating a contextually grounded instructional product and design principles for sustainability-oriented learning. Thus, the novelty of this study lies in integrating ESD principles, the local context of Garut batik production and its waste, Phase C IPAS, ecoprinting as an experiential learning activity, and sustainability-oriented assessment within a single Student Worksheet designed to foster sustainability awareness among fifth-grade elementary school students.

METHOD

This study employed a Design-Based Research (DBR) approach to develop, implement, and evaluate an ecoprinting-based Student Worksheet (LKPD) aimed at fostering sustainability awareness among fifth-grade elementary school students. The DBR approach was selected because it enables the systematic development of educational products through iterative cycles of needs analysis, design, implementation, evaluation, and reflection (Collins et al., 2004). This process results not only in a feasible instructional product but also in the formulation of design principles that can be applied to similar educational contexts (Reeves, 2006). Anderson and Shattuck (2012) describe DBR as a research approach that integrates theory development with educational practice through collaboration between researchers and practitioners in authentic learning settings (see also Wang & Hannafin, 2005). This study adopted the DBR procedure proposed by Reeves (2006), which consists of four phases, as illustrated in Figure 1.

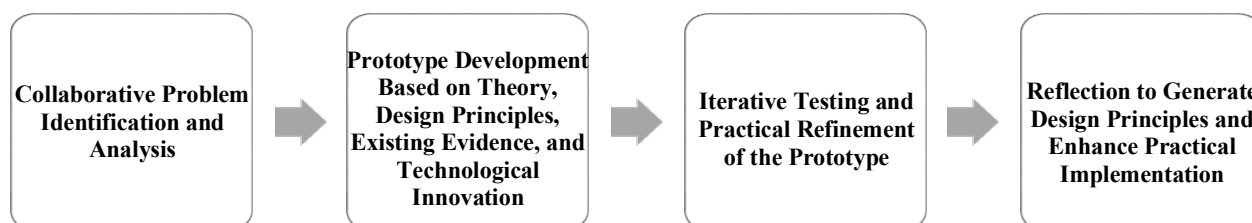


Figure 1. Reeves' Design-Based Research Model

The research procedure followed the Design-Based Research (DBR) model proposed by Reeves (2006), which consists of four interconnected phases. The first phase, problem identification and needs analysis, was conducted through an interview with one fifth-grade teacher, classroom observation, and document analysis of the teacher and student source books, learning objectives, curriculum documents, previous relevant studies, and students' previous learning outcomes.

This phase was intended to identify instructional needs and challenges related to the integration of Education for Sustainable Development in IPAS learning. The second phase involved the development of the Student Worksheet prototype, which was designed based on the needs analysis by integrating ESD principles, the local context of synthetic dye waste from Garut batik production, and ecoprinting activities as contextual and experiential learning experiences. The prototype was subsequently subjected to expert validation by specialists in pedagogy, instructional material development, and environmental education to assess its feasibility and obtain recommendations for revision. The third phase comprised one classroom implementation

and evaluation cycle conducted over two meetings with 31 fifth-grade students aged 10–11 years, consisting of 18 girls and 13 boys.

The classroom was situated in a rural area of Garut with direct access to natural surroundings, including rice fields, gardens, and mountainous areas. The students' daily lives were closely connected to these natural surroundings and resources. Before the implementation, students had received brief instruction on the *Environmental Issues Threatening Life* topic through a predominantly lecture-based approach and had no prior experience with ecoprinting activities. The Student Worksheet was then implemented in IPAS learning to provide contextual and hands-on experiences related to environmental issues and responsible resource use. Data were collected through essay tests, questionnaires, observation sheets, and documentation to examine students' sustainability-related knowledge, attitudes, and actions. All 31 students participated in both classroom meetings and completed all instruments administered during the study. The fourth phase, reflection and product refinement, involved reviewing the expert validation results and classroom implementation data to identify aspects requiring improvement and to produce the refined final version of the Student Worksheet. Because the study involved one classroom implementation cycle, the present study does not claim multiple repeated prototype-testing cycles; rather, the DBR framework was used to systematically guide problem identification, prototype development, expert review, classroom implementation, reflection, and product refinement. The study was conducted at SDN Sindanggalih IV, Garut Regency, West Java, Indonesia, during the second semester of the 2024/2025 academic year. Participants were selected purposively because they were enrolled in Phase C IPAS and were studying the topic *Environmental Issues Threatening Life*, which was directly aligned with the content and objectives of the developed Student Worksheet.

Data were collected through semi-structured interviews, document analysis, expert validation, cognitive essay tests (pretest–posttest), affective questionnaires, observation sheets, and anecdotal records. The interviews and document analysis were conducted during the preliminary study to identify instructional needs and contextual problems. Semi-structured interviews were conducted with the fifth-grade teacher to explore several aspects, including the implementation of Integrated Science and Social Studies (IPAS) instruction, students' sustainability awareness, the use and quality of Student Worksheets (SWs), and the teacher's knowledge of ecoprinting and its relevance to the local environmental issue of synthetic dye waste generated by the Garut batik industry. Document analysis was undertaken to collect supporting data and theoretical foundations for the design of the Student Worksheet and the implementation of the study. Subsequently, expert validation was conducted to evaluate the feasibility of the developed Student Worksheet. The validation process involved three experts representing IPAS content, instructional design, and pedagogy, who assessed the content, design, and pedagogical aspects of the instructional material and provided recommendations for its improvement.

The instruments were developed to operationalize sustainability awareness in the context of elementary-school learning by considering the interrelated dimensions of knowingness, attitudes, and behavior described in the sustainability consciousness framework of Gericke et al. (2019) and instruments for measuring students' sustainability competencies (Waltner et al., 2019). In the present study, the cognitive, affective, and psychomotor domains were used as assessment domains to operationalize these dimensions in classroom learning, rather than being treated as

equivalent to sustainability awareness itself. The cognitive domain was assessed using a pretest–posttest consisting of four essay questions addressing students’ understanding of resource limitations, analysis of environmental impacts, and knowledge of sustainable solutions. The questions required students to compare natural and synthetic dyes, explain why plant materials should not be harvested excessively, analyze the effects of synthetic dye waste on living organisms and the environment, and explain reasons for using natural dyes in the ecoprinting context. These questions were designed to encourage students to consider resource limitations, human–environment interdependence, cause-and-effect relationships, and the consequences of resource-use decisions.

The affective domain was assessed using a 20 item questionnaire, consisting of 11 positively worded and 9 negatively worded statements, using a four-point Likert scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree) (Riduwan, 2016). The items addressed empathy toward nature, personal responsibility, concern about environmental pollution and its effects on human health and living organisms, participation in environmental protection, and responsible consideration of natural materials. The use of natural materials was not assumed to be inherently sustainable; rather, the items were interpreted in relation to students’ willingness to use natural resources responsibly and consider the consequences of material choices.

The psychomotor domain was assessed through 9 observable behaviors during the ecoprinting activities, including responsible collection of plant materials, appropriate water use, waste separation, following the activity procedures, helping peers, completing tasks, communicating sustainability-related information, reminding peers about responsible resource use, and sharing sustainability-related information with the school community. Thus, the behavioral assessment focused on responsible resource use, active participation and collaboration, and communication of sustainability-related practices, rather than merely evaluating the resulting ecoprint product. All instruments were validated through expert judgment before classroom implementation. The experts reviewed the relevance, clarity, and appropriateness of the items and indicators in relation to the intended sustainability awareness constructs and the Phase C IPAS learning context. Revisions were made based on the experts’ recommendations before administration. No empirical item validity or statistical reliability testing was conducted, as instrument validation in this study relied on expert judgment within the DBR development process. The four essay questions were scored using predetermined scoring criteria based on the accuracy, completeness, relevance, and reasoning demonstrated in students’ responses (Arikunto, 2016). The pretest and posttest were used to examine changes in students’ sustainability-related knowledge, whereas the affective questionnaire and psychomotor observation were used to describe students post-implementation attitudes and behaviors. Because no pre-intervention affective questionnaire or psychomotor observation was administered, these findings are interpreted as post-implementation levels rather than evidence of improvement.

Data were analyzed using both qualitative and quantitative data analysis techniques. The qualitative data consisted of interview transcripts, document analysis, and anecdotal records, whereas the quantitative data comprised the results of the cognitive essay tests, affective questionnaires, and classroom observation sheets. The qualitative data were analyzed using the proposed by Miles et al. (2018), as illustrated in

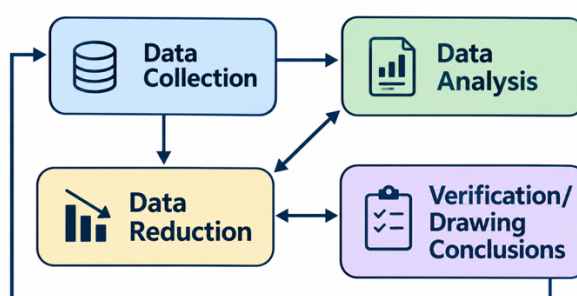


Figure 2. Interactive Data Analysis Model for Qualitative Data

The qualitative data analysis involved describing and interpreting information obtained from interviews with the fifth-grade teacher, document analysis, and anecdotal records, including participants' responses, suggestions, feedback, and comments. These data were analyzed using the interactive data analysis model proposed by Miles et al. (2018), as illustrated in Figure 2. The analysis began with data collection, during which qualitative information was gathered from multiple sources. The collected data were then subjected to data reduction, which involved selecting, organizing, and systematically categorizing the information. Subsequently, data display was conducted to facilitate data interpretation and support the planning of subsequent actions. Finally, conclusion drawing and verification were performed by interpreting the findings in relation to the research objectives and confirming the consistency of the conclusions. Quantitative data analysis was conducted to address the research objectives concerning the development of an ecoprinting-based Student Worksheet (SW) to foster sustainability awareness among fifth-grade elementary school students by incorporating the local environmental issue of synthetic dye waste from the Garut batik industry. The quantitative analysis was designed to evaluate the design, feasibility, implementation, and effectiveness of the developed instructional product. Product feasibility was determined through expert validation conducted by experts in IPAS content, instructional design, and pedagogy.

RESULTS AND DISCUSSION

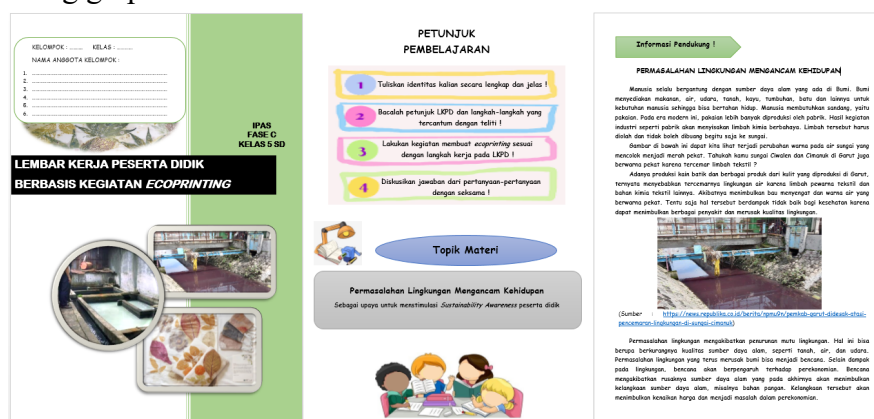
Results

The development of the ecoprinting-based Student Worksheet (SW) followed the Design-Based Research (DBR) approach, which comprises four phases: problem identification and analysis, prototype development, iterative testing, and reflection. The initial phase involved problem identification and needs analysis through semi-structured interviews and document analysis. This phase generated comprehensive findings covering four major aspects: performance analysis, resource analysis, needs analysis, and curriculum analysis.

The performance analysis revealed that Integrated Science and Social Studies (IPAS) instruction was predominantly delivered through conventional lecture and discussion methods. The existing instructional materials provided limited opportunities for students to engage in exploratory and hands-on learning activities. Furthermore, no ecoprinting-based Student Worksheet designed specifically to foster sustainability awareness was available, and local environmental issues, particularly the problem of synthetic dye waste generated by the Garut batik

industry, had not been integrated into IPAS learning. Interviews indicated that the concept of sustainability awareness was still unfamiliar to both teachers and students and had not yet been explicitly incorporated into classroom instruction. The initial cognitive assessment further provided baseline evidence of students' limited sustainability-related knowledge, particularly concerning resource limitations, environmental impacts, and sustainable solutions. The pretest results showed that only 29.03% of students achieved the predetermined learning mastery criterion, indicating that students' initial understanding of sustainability-related environmental issues was still limited. This finding was interpreted specifically as evidence of limited knowingness, rather than as a direct measure of students' overall sustainability awareness, which also encompasses attitudes and behaviors. The resource analysis indicated that the school had implemented the Merdeka Curriculum, in which teachers act as learning facilitators; however, the utilization of instructional media remained limited. Therefore, the Student Worksheet was developed in a printed format to accommodate the school's available resources and classroom conditions. Finally, the curriculum analysis was conducted to ensure that the developed instructional product aligned with the intended Learning Outcomes of the Merdeka Curriculum. Accordingly, the Student Worksheet was designed around the Phase C IPAS topic *Environmental Issues Threatening Life*, while integrating local environmental issues as an authentic learning context.

During the prototype development phase, the ecoprinting-based Student Worksheet (SW) was designed by considering three main aspects: visual appearance, content relevance, and the appropriateness of learning activities. The Student Worksheet consisted of six components: (1) cover page, (2) learning instructions, (3) intended learning outcomes, (4) supporting information, (5) learning tasks, and (6) activity procedures. The instructional material was developed using clear and age-appropriate language, an attractive visual design, and informative content, while incorporating ecoprinting-based learning activities throughout the worksheet. The content of the Student Worksheet was organized into three sequential learning stages: understanding, application, and reflection. These activities were centered on the topic of environmental problems caused by synthetic dye waste generated from the Garut batik industry, providing students with an authentic local context for learning. Each activity was intentionally designed to foster sustainability awareness across the cognitive, affective, and psychomotor domains. In addition, all components of the Student Worksheet, together with the research instruments, were designed by the researcher using graphical elements created with Canva and other relevant visual resources.



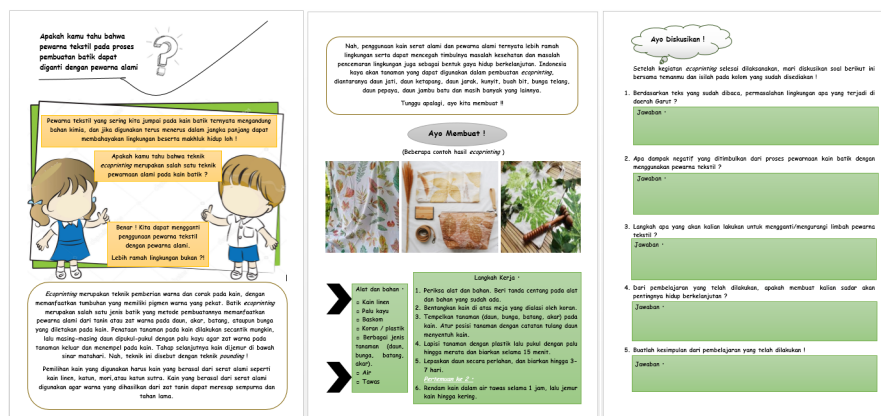


Figure 3. Layout of the Ecoprinting-Based Student Worksheet

Following the development of the Student Worksheet (SW), expert validation was conducted to evaluate its feasibility. The validation process involved three experts, comprising an IPAS content expert (elementary school teacher), an instructional design expert (university lecturer), and a pedagogy expert (university lecturer). The results indicated that the evaluations from all three experts fell within the Very Feasible category. The detailed results of the expert validation are presented below.

Table 5. Expert Validation Results

Validation Instrument	Presentase	Category
IPAS Content Expert	100%	Very Feasible
Instructional Design Expert	99%	Very Feasible
Pedagogy Expert	100%	Very Feasible

The implementation phase was conducted after the Student Worksheet (SW) had undergone expert judgment and revision. The field implementation consisted of two instructional meetings, each lasting 2×35 minutes, involving 31 fifth-grade students organized into six heterogeneous groups. Group assignment was conducted randomly by having students draw rolled pieces of paper containing group numbers, ensuring that students worked collaboratively with different peers. In the first meeting, the teacher introduced the learning objectives and the environmental issue related to synthetic dye waste from local batik production, guided students in exploring the information and activities presented in the Student Worksheet, and facilitated discussion about resource limitations, environmental impacts, and sustainable alternatives. Students worked collaboratively to examine the learning materials, discuss the environmental issue, and prepare the materials required for the ecoprinting activity. Before the practical activity, the teacher provided instructions on the appropriate use of plant materials, water, and equipment, including specific safety instructions for using the wooden mallet. In the second meeting, students continued the ecoprinting activity using the pounding technique. Students arranged plant materials on the fabric, covered them with plastic, and pounded the materials using a wooden mallet to transfer the natural pigments onto the fabric. The teacher provided guidance before the pounding activity and supervised the students throughout the process. The distance between groups was also arranged to provide sufficient working space and maintain students' comfort and safety during the activity. Students collaborated within their groups while following the procedures provided in the Student Worksheet and were encouraged to use materials and water responsibly, manage waste

appropriately, and assist peers during the activity. At the end of the learning activities, students reflected on the relationship between resource use, environmental protection, and sustainable practices. The assessment of sustainability awareness was conducted using pretest–posttest essay tests for the cognitive domain, a post-implementation questionnaire for the affective domain, and classroom observation for the psychomotor/behavioral domain. All 31 students participated in both meetings and completed all instruments administered during the implementation.

The cognitive assessment showed an increase in students' mean scores from 29.03 on the pretest to 91.77 on the posttest, resulting in a mean N-Gain of 89.73%, which was categorized as high (Hake, 1998). Examination of the individual scores showed that the N-Gain ranged from 29.41% to 100%, with a median of 100%. A total of 28 students (90.32%) achieved a high N-Gain, two students (6.45%) achieved a medium N-Gain, and one student (3.23%) achieved a low N-Gain. Furthermore, 20 of the 31 students (64.52%) obtained a posttest score of 100, indicating a concentration of scores at the upper end of the scale and suggesting a potential ceiling effect. The individual distribution of pretest, posttest, and N-Gain scores is presented in table 6. Because the same four essay questions were administered in both the pretest and posttest, the observed increase should be interpreted cautiously, as familiarity with the test items may have contributed to the improvement. The high N-Gain therefore indicates substantial improvement in students' demonstrated cognitive performance within the intervention context, rather than conclusive evidence of the independent causal effectiveness of the Student Worksheet.

Table 6. Individual Pretest, Posttest, and N-Gain Scores of Students

Student	Pretest	Posttest	N-Gain (%)
S1	45	85	72,72
S2	30	90	85,71
S3	25	70	60
S4	20	95	93,75
S5	75	100	100
S6	35	95	92,30
S7	50	100	100
S8	30	100	100
S9	10	45	38,88
S10	15	80	76,47
S11	20	100	100
S12	20	100	100
S13	25	95	93,33
S14	30	100	100
S15	25	100	100
S16	40	100	100
S17	15	40	29,41
S18	20	100	100
S19	15	100	100
S20	25	100	100
S21	20	80	75
S22	50	100	100
S23	20	95	93,75
S24	30	100	100
S25	20	95	93,75

Student	Pretest	Posttest	N-Gain (%)
S26	25	100	100
S27	50	100	100
S28	40	100	100
S29	40	100	100
S30	20	100	100
S31	15	80	76,47

Table 8. Mean Percentage Scores of the Affective Domain of Sustainability Awareness

Affective Indicators of Sustainability Awareness	Mean Score (%)
Empathy toward Nature	74 %
Personal responsibility	64,3 %
Appreciation of Natural Materials	68,20 %
Class Mean 68, 50 %	

Table 9. Mean Percentage Scores of the Psychomotor Domain of Sustainability Awareness

Psychomotor Indicators of Sustainability Awareness	Mean Score (%)
Responsible Consumption Practices	87,90 %
Active Participation	86,02 %
Dissemination of Sustainability Awareness	86,02 %
Class Mean 86,64 %	

The final phase involved reflection and evaluation following the two-meeting classroom implementation. The reflection was based on the findings from expert validation, the implementation of the developed Student Worksheet (SW) across the two instructional meetings, and the assessment of students' sustainability awareness through the cognitive, affective, and psychomotor/behavioral domains. The evaluation considered students' responses and performance during the ecoprinting activities, the results of the cognitive essay tests, the post-implementation affective questionnaire, and classroom observations. The reflection identified the strengths and limitations of the developed Student Worksheet and was used to refine the final product. Based on the evidence obtained throughout the DBR process, several design principles were formulated: (1) integrating environmental, social, and economic dimensions of sustainability; (2) using authentic local sustainability issues as learning contexts; (3) providing experiential and hands-on learning activities; (4) connecting learning activities with students' sustainability-related knowingness, attitudes, and behaviors; (5) providing age-appropriate procedures, teacher guidance, and safety arrangements for practical activities; and (6) incorporating reflection to help students connect practical experiences with responsible resource use and sustainable practices. These principles were derived from the needs analysis, expert feedback, two-meeting classroom implementation, and evaluation findings and may serve as a design reference for developing similar sustainability-oriented instructional materials in elementary-school contexts.

Discussion

Based on the research findings, the developed ecoprinting-based Student Worksheet (SW) was found to be highly feasible as an instructional material for fostering students' sustainability awareness in Phase C Integrated Science and Social Studies (IPAS) on the topic *Environmental Issues Threatening Life* by incorporating the local environmental issue of synthetic dye waste generated from the Garut batik industry. The feasibility of the developed Student Worksheet was confirmed through expert validation, with percentage scores of 100% from the IPAS content expert, 99% from the instructional design expert, and 100% from the pedagogy expert, all of which were classified as Very Feasible. Furthermore, the research instruments, including the cognitive essay test (pretest–posttest), affective questionnaire, and psychomotor observation sheet, also achieved high, very good, and high categories, respectively, indicating that they were appropriate for use as data collection instruments. These findings indicate that the developed Student Worksheet satisfies the criteria of content validity, construct validity, linguistic appropriateness, and presentation quality. This finding is consistent with Plomp (2013), who argued that an instructional product can be considered feasible when it meets established validity criteria based on expert judgment.

The high level of feasibility demonstrated that the developed Student Worksheet met the essential criteria for instructional quality, including content appropriateness, conceptual framework, content presentation, language use, layout, visual design, and student-centered learning activities. This finding is consistent with Agustin (2024), who argued that experience-based learning, which actively engages students through hands-on activities, environmental exploration, and the use of natural materials, can effectively promote character development and deepen children's understanding of their natural environment from an early age. Moreover, the instructional content successfully integrated local environmental issues while aligning with the Learning Outcomes for Phase C IPAS. The student worksheet also accommodated the indicators of sustainability awareness across the cognitive, affective, and psychomotor domains. This integration of local environmental contexts reflects the principles of ESD, which emphasize the importance of contextualized learning experiences that enable students to understand environmental issues within their own communities and actively participate in addressing them (UNESCO, 2020; Kioupi & Voulvoulis, 2022). Similarly, Supriatna (2016) emphasized that learning based on local environmental contexts fosters ecological awareness by engaging students directly with authentic environmental problems. From a pedagogical perspective, the ecoprinting activities implemented in the Student Worksheet followed a structured learning sequence consisting of the understanding, application, and reflection stages. Minor revisions were made to the visual presentation of the ecoprinting activities based on feedback provided by the instructional design expert during the validation process. Following these revisions, the developed Student Worksheet was considered feasible for classroom implementation as an instructional resource.

The developed Student Worksheet was also designed based on the ecoprinting learning sequence, which consists of observing and understanding environmental issues, applying solutions through ecoprinting practice, and reflecting on the learning experience. This sequence is consistent with Kolb's Experiential Learning Theory, which posits that learning becomes more meaningful when students engage in concrete experiences, reflect on those experiences, construct new knowledge, and apply it in authentic contexts (Kolb, 2015; Kolb & Kolb, 2005). Through the

ecoprinting activities, students not only learned about the environmental impacts of synthetic dyes used in the Garut batik industry but also experienced the use of natural plant materials as environmentally friendly alternatives to synthetic dyes. Such student-centered learning activities have been shown to enhance students' engagement while simultaneously fostering sustainability competencies (Brundiens et al., 2021).

From a descriptive perspective, the implementation of the ecoprinting-based Student Worksheet was associated with a substantial increase in students cognitive performance related to sustainability awareness. The mean score increased from 29.03 on the pretest to 91.77 on the posttest, with a mean normalized N-Gain of 89.73%, categorized as high. The individual score distribution showed that 28 of 31 students (90.32%) achieved a high N-Gain, while 20 students (64.52%) obtained the maximum posttest score of 100. These findings indicate a substantial increase in students' demonstrated knowledge concerning resource limitations, environmental impacts, and sustainable solutions following the implementation. However, the results should be interpreted cautiously because the study did not include a comparison group and no inferential statistical analysis was conducted. Furthermore, the same four essay questions were used in the pretest and posttest, which may have introduced a familiarity or practice effect, while the concentration of scores at the upper end of the posttest distribution suggests a potential ceiling effect. Therefore, the high N-Gain should be interpreted as descriptive evidence of increased cognitive performance within the intervention context, rather than conclusive evidence that the Student Worksheet independently caused the observed improvement. The finding is nevertheless consistent with the objectives of ESD, which emphasize the development of knowledge, values, and competencies for sustainable development (UNESCO, 2020). It also aligns with Gericke et al. (2019), who conceptualize the knowingness component of sustainability consciousness as students' knowledge and understanding of sustainability-related issues across environmental, social, and economic dimensions. Thus, the observed cognitive increase suggests that the ecoprinting-based Student Worksheet provided students with opportunities to engage with sustainability-related knowledge in a contextual learning setting.

In the affective domain, the post-implementation questionnaire showed a class mean percentage of 68.50%, which was categorized as very good according to the predetermined criteria. This result indicates that, following the implementation of the ecoprinting-based Student Worksheet, students demonstrated relatively positive attitudes toward environmental conservation, particularly in relation to environmental concern, personal responsibility, and appreciation of natural materials. However, because the affective questionnaire was administered only after the intervention and no baseline affective measurement or comparison group was included, the result cannot be interpreted as evidence of an improvement or change in students' attitudes. Rather, the finding describes the level of students' affective responses observed after participating in the learning activities. This interpretation is consistent with UNESCO (2020), which emphasizes that Education for Sustainable Development (ESD) seeks to develop learners' values, attitudes, and commitment to sustainable development. Similarly, Gericke et al. (2019) conceptualize sustainability consciousness through interconnected dimensions of knowingness, attitudes, and behavior across environmental, social, and economic aspects. In this study, the affective result therefore provides descriptive evidence that the ecoprinting-based Student Worksheet was associated with positive post-implementation attitudes toward sustainability, but

further research using pre- and post-intervention affective measures or a comparison group is needed to determine whether the learning intervention produces measurable changes in students' attitudes.

In the psychomotor domain, students achieved a class mean percentage score of 86.64%, which was categorized as very good. These results indicate that students were able to effectively demonstrate the practical skills required in the ecoprinting activities, including selecting appropriate natural materials, arranging leaf patterns, performing the ecoprinting process, and producing environmentally friendly textile products in accordance with the procedures introduced during the learning activities. The findings suggest that hands-on learning effectively enhanced students' practical skills through direct experience. This finding is consistent with Kolb's Experiential Learning Theory, which emphasizes that concrete learning experiences play a crucial role in developing durable knowledge and practical skills (Kolb, 2015). Likewise, Brundiers et al. (2021) argued that action-oriented learning is an effective approach for developing sustainability competencies because it actively engages learners in addressing authentic environmental challenges. The high level of psychomotor achievement observed in this study indicates that the ecoprinting-based Student Worksheet not only strengthened students' technical skills but also encouraged them to translate sustainability concepts into environmentally responsible practices through authentic learning experiences.

CONCLUSION

The findings of this study indicate that the ecoprinting-based student worksheet developed for the phase C IPAS topic *Environmental Issues Threatening Life*, incorporating the local environmental issue of synthetic dye waste generated by the Garut batik industry, met the criteria for a highly feasible instructional resource. Expert validation yielded an average feasibility score of 99.66%, indicating that the Student Worksheet was considered appropriate in terms of content, language, instructional structure, integration of local environmental issues, ecoprinting activities, and sustainability-related learning indicators. Descriptively, students' cognitive performance increased from a mean pretest score of 29.03 to a mean posttest score of 91.77, with a mean normalized N-Gain of 89.73%, categorized as high. However, this increase should be interpreted cautiously because the study involved one group without a comparison group, the same four essay questions were used in the pretest and posttest, and the posttest scores showed a potential ceiling effect. The post-implementation affective questionnaire yielded a class mean of 68.50%, while the behavioral observation yielded a mean of 86.64%, describing students' attitudes and observed behaviors following the implementation rather than demonstrating changes from baseline. Therefore, the findings provide descriptive evidence that the Student Worksheet was feasible and associated with positive cognitive, affective, and behavioral outcomes within the implementation context, but they do not establish a causal effect on students' overall sustainability awareness. The study was limited by its small sample from a single elementary school, brief two-meeting implementation, absence of a control or comparison group, repeated use of identical pretest–posttest items, and lack of long-term follow-up to examine retention or transfer of sustainability-related knowledge and behaviors. Future research should involve larger and more diverse samples, comparison groups, parallel assessment forms, longer implementation periods, and follow-up assessments to examine the sustainability of learning outcomes and the transfer of sustainability

practices to students' everyday lives. Within these limitations, the developed Student Worksheet provides a contextual instructional resource for integrating Education for Sustainable Development (ESD) and locally relevant sustainability issues into Phase C IPAS learning.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Sriwianti : Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Validation, Visualization, Project administration, Writing – original draft, and Development of the ecoprinting-based student worksheet.

Mubiar Agustin : Conceptualization, Methodology, Supervision, Validation, Resources, Writing – review & editing, and Design consultation.

Neni Maulida : Methodology, Validation, Supervision, Writing – review & editing, Design consultation, and Product evaluation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have **no known competing financial interests or personal relationships** that could have appeared to influence the work reported in this paper. This study was conducted independently as part of the first author's master's thesis under the academic supervision of the second and third authors. All authors contributed to the study according to their respective roles, approved the final version of the manuscript, and take full responsibility for the accuracy and integrity of its content.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

ETHICS STATEMENT

This study did not require formal approval from a Research Ethics Committee because it involved educational research with minimal risk to participants. Prior to data collection, research permission was obtained from the Faculty of Educational Sciences, Universitas Pendidikan Indonesia, and SDN Sindanggalih IV, Garut Regency, where the study was conducted. Informed consent was obtained from the school principal, the fifth-grade classroom teacher, and the parents or legal guardians of all participating students before their involvement in the study. Participation was entirely voluntary, and all participant information was treated confidentially throughout the data collection, analysis, and reporting processes in accordance with established ethical principles for educational research.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing, sentence restructuring, improving readability, and enhancing the overall presentation of the manuscript. All AI-assisted outputs were carefully reviewed, verified, and substantially revised by the authors to ensure their accuracy, scientific validity, and compliance with academic writing standards. The authors take full responsibility for the content of this manuscript. All aspects of the research, including the study design, data collection, data analysis, interpretation of the findings, and the conclusions presented, were conducted solely by the authors.

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