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Irdalisa Irdalisa
Universitas Muhammadiyah Prof. DR. HAMKA, Indonesia, irdalisa@uhamka.ac.id

Paidi Paidi
Universitas Negeri Yogyakarta, Indonesia, paidi@uny.ac.id

Rashmi Ranjan Panigrahi
GITAM School of Business, GITAM (Deemed to Be University), India, rashmipanigrahi090@gmail.com

Erlia Hanum
Universitas Al Muslim, Indonesia, erliahanum@umuslim.ac.id

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Project-Based Learning on STEAM-Based Student's Worksheet with Ecoprint Technique: Effects on Student Scientific Reasoning and Creativity

Irdalisa[1]*, Paidi[2], Rashmi Ranjan Panigrahi[3], Erlia Hanum[4]
[1]Universitas Muhammadiyah Prof. Dr. HAMKA, Jakarta, Indonesia
[2]Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.
[3]GITAM School of Business, GITAM (Deemed to Be University), Visakhapatnam, India
[4]Universitas Al Muslim, Aceh, Indonesia
* Corresponding Author. E-mail: irdalisa@uhamka.ac.id

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Abstract: The use of conventional worksheets will likely limit students' ability to explore themselves and their critical and analytical thinking, which can enhance their scientific reasoning and creativity. This situation demands the need for student worksheets linked to technology, art, and mathematics to adapt to the demands of the times. This study aims to determine the effect of project-based learning by analyzing student worksheets based on science, technology, engineering, arts, and mathematics (STEAM) using the eco-print technique on students' scientific reasoning and creativity. This research is a quasi-experimental study. The research sample is 160 students of a public senior high school in Jakarta, randomly selected and grouped into control and experimental groups, each consisting of 80 students. Data on scientific reasoning were collected using a test, while student creativity was measured with a questionnaire and observation sheet. The data obtained were analyzed using a one-way analysis of covariance at the significance level of 5%. The results show that the application of project-based learning on STEAM-based student worksheets using the eco-print technique significantly affects the students' achievement of scientific reasoning and creativity. The use of STEAM-based student worksheets with the eco-print technique serves as an innovative learning media to enhance the quality of education, as it can facilitate and increase active student engagement in collaborative projects that integrate various STEAM elements, thereby improving student competencies.

Keywords: eco-print, PjBL, scientific reasoning, STEAM, student creativity, worksheet

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INTRODUCTION

In the 21st century, education is tailored to emphasize skills relevant to the modern era, such as critical thinking, creative and innovative thinking, communication, and collaboration (Nurhasanah et al., 2024). In alignment with the 21st-century educational paradigm, students are encouraged to acquire the skills of critical thinking, inquiry, problem-solving, meaningful contextual understanding, and engaging pedagogical methodologies to achieve learning objectives (Puangpunsi, 2021). Teachers should endeavor to ascertain and explore the existing concepts held by students and assist in integrating them with new knowledge to create meaningful learning experiences (Hsbollah & Hassan, 2022). The learning process implemented by teachers must be able to combine literacy skills, knowledge, skills, behavior, and mastery of technology. The learning process extends beyond memorizing concepts or mere facts. It involves linking these concepts to real-world problems so that the acquired knowledge is well comprehended and less likely to be forgotten (Dixon & Brown, 2012).

Numerous studies indicate the positive impact of implementing various learning models, including requiring students to participate in constructing and organizing knowledge directly, considering alternative answers, engaging directly in research and data analysis, and communicating directly with the community (Barron & Chen, 2008). One learning model that provides students with opportunities to explore meaningful content and collaborate experimentally is the project-based learning (PjBL) model (Belwal et al., 2020). PjBL forms a student-centric approach to teaching, marked by active student participation, constructive inquiry, goal establishment, collaboration, communication, and reflection within real-world practices (Zen et al., 2022) by presenting certain problem situations or problems to students and motivating students to identify and provide solutions (Anazifa & Djukri, 2017). In the PjBL model, the product design process empowers learners to integrate and reconstruct knowledge, enhance professional competencies, boost interest, and improve collaborative abilities among participants (Guo et al., 2020).

Project-based learning demonstrates suitability for integrating science, technology, engineering, arts, and mathematics (STEAM). It has proven to be the most successful approach worldwide for incorporating artistic components into schools (Jantassova et al., 2023). The STEAM approach has been widely employed to create comprehensive learning experiences. Numerous studies have reported the varied impacts of STEAM, among which are its ability to drive multidisciplinary problem-solving and motivate students (Asrizal et al., 2023). However, STEAM does not affect learning outcomes, as seen from the lack of student interest (Min et al., 2021). Implementing STEAM in schools can be challenging due to its interdisciplinary nature and the need for adequate facilities and resources to support various knowledge domains (Jeong & Kim, 2015). The PjBL model and the STEAM approach have similar goals in directing students to solve problems with technological products (Herlita et al., 2023).

The utilization of worksheets can facilitate knowledge acquisition, enhance students' fundamental competencies, and encourage the active involvement of both teachers and students in project-based activities (Suwarno & Hasanudin, 2020). However, only a few schools implemented the integrated STEAM worksheets (Sa’adah, Ullyatus., 2022). STEAM-based student worksheets are still rarely found, especially in Indonesian schools (Patresia et al., 2020). STEAM is highly significant for fostering scientific abilities and effectively addressing open-ended, real-world tasks within students' future careers, as it shapes their scientific reasoning. (Zulkipli et al., 2020).

The 21st century demands students to be able to think and reason scientifically. Scientific reasoning is one of the century skills that need to be trained because it is the basis for the development of other skills (Saad et al., 2017). Scientific reasoning strongly correlates with cognitive abilities, where effective scientific reasoning involves logic, justification, rational thinking, and decision-making (Bao et al., 2009). Scientific reasoning is defined as the search for knowledge and coordination between theory and evidence. It is synonymous with experimentation (Choowong & Worapun, 2021). It plays a role in decision-making in everyday life through scientific processes, as a construct or predictor of student learning outcomes (Firdaus, 2021).

Students' scientific reasoning is complicated to hone well if the learning process is inappropriate (Luzyawati et al., 2021). The lack of quality teachers in the learning process who train students' scientific reasoning makes students less accustomed to solving problems that require them to think convergently (Hasruddin & Aulia, 2023), so they lack a broad way of thinking (Shofiyah et al., 2013). Students' lack of scientific reasoning skills is also attributed to students' inadequate attention to teachers' explanations. Students tend to memorize scientific concepts without comprehending the underlying meaning (Daryanti et al., 2015). Forming students' scientific reasoning is challenging due to its perceived status as an indicator of the complexity of students' cognitive, psychological, and effective social frameworks. This is considered highly significant in improving learning outcomes within the school environment (Bezci & Sungur, 2021).

Creative thinking could be predictive of scientific reasoning (Willemsen et al., 2023). Enhancing students' creativity is inextricably linked to the significance of scientific reasoning in connection to conceptual understanding. Creative thinking is a mental process that incorporates cognitive functions (Hargrove, 2013). Students are expected to have received creative thinking instruction to generate highly innovative products. The ability to think creatively is essential for answering multi-safety issues both now and in the future (Leasa et al., 2023). To address global challenges, creativity, and insight can drive innovation and better learning environments. (Evans, 2020).

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Creativity is the primary skill that receives special attention in learning (Aguilera & Ortiz-Revilla, 2021). Creativity involves the combination of uniqueness and utility, merging interaction, talent, processes, and environment to generate novel and valuable products from something that did not previously exist (Beghetto, 2005) (Pllana, 2019). Various findings claim that STEAM can enhance student creativity (Asrizal et al., 2023); the element of art in STEAM plays an important role (Boy, 2013). Several studies show that learning by applying art more deeply can produce challenging work (Liu et al., 2023).

Art that can be associated with the learning process is the application of the eco-print technique. It is a method of decorating fabric by using various plants to extract their natural colors (Fatmala & Hartati, 2020). It is considered applicable in learning because its process involves techniques, art, technology, and mathematics (Widiantoro, 2020). The product creation process in the PjBL model empowers students to integrate and reconstruct student knowledge, strengthen professional competence, increase motivation, and refine students' collaborative abilities (Guo et al., 2020). The integration of project-based learning with STEAM elements encourages students to explore innovative and imaginative ways to address challenges, present data, encourage innovation, and bridge multiple disciplines (Dyer, 2019). Project-based learning on STEAM-based students' worksheets with the eco-print technique is a crucial subject that has received less attention and is still rarely used in biology learning, so this research will help broaden the perspective to apply it in current learning. Hence, it can be utilized as project-based learning with STEAM elements so that students can acquire all fields of knowledge. Therefore, there is a need to design guidelines that integrate STEAM into project-based learning as an advanced organizer to assist students in activities and structure observations in the learning environment that do not confuse students (Lee, 2014). This research aims to determine the effectiveness of implementing project-based learning using STEAM-based worksheets alongside the eco-print technique in enhancing students' scientific reasoning and creativity. The research tries to address the following research questions: Does the use of project-based learning on STEAM-based students' worksheets with eco-print technique affect student scientific reasoning and creativity?

LITERATURE REVIEW

Project Based Learning (PjBL)

John Dewey developed the problem-based learning (PjBL) model based on 'learning by doing', emphasizing learning through direct experiences and student-centered education (Maida, 2011). PjBL creates a conducive learning environment by applying skills, thereby enhancing the quality of learning and facilitating the achievement of higher cognitive levels (Yamin et al., 2017). It encourages students collectively to organize their knowledge to seek solutions in problem-solving and fostering critical and creative thinking (Darling-Hammond et al., 2020).

Previous studies have provided information regarding implementing project-based learning (PjBL) in education. These include a focus on student worksheet-based PjBL(Suwarno & Hasanudin, 2020) ; blended PjBL models (Agustina et al., 2022); hybrid-PjBL (Rahardjanto et al., 2019); ethno-STEM-PjBL (Martawijaya et al., 2023); PjBL-STEM (Jamali et al., 2017); PJBL-STEAM (Chistyakov et al., 2023); and e-LKPD assisted PJBL-STEM (Ayuni et al., 2022). While several prior studies have addressed PjBL, there remains a scarcity of research reports related to PjBL-STEAM concerning scientific reasoning. Therefore, further research is necessary to explore these distinct variables.

Science, Technology, Engineering, Arts, and Mathematics (STEAM)

Georgette Yakman's concept of science, technology, engineering, arts, and mathematics (STEAM) emerged in the early 2000s and gained further acceptance by the mid-2000s (Pearson, 2022). STEAM was first applied in the United States in 2007 (Daugherty, 2013). The integration of STEAM into education as an innovation was a response to the growing need to enhance students' competencies across various domains. STEAM stimulates students' creativity and collaboration (Belbase et al., 2022). Previous research studies on STEAM have focused on its implementation concerning cooperative working skills and career choices (Asrizal et al., 2023), student learning achievements (Asrizal et al., 2023), motivation, and outcomes in science learning (Safitri et al., 2023), as well as students' critical thinking abilities (Syukri et al., 2022).

Learning models like PjBL can be integrated with the STEAM approach. Research (Ananda et al., 2023) demonstrates how integrating design thinking with STEAM-PjBL can enhance students'

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critical thinking abilities in learning chemistry related to problems in everyday life. This is just one of several studies that combine STEAM and PjBL. A novel approach to teaching ecological concepts, project-based e-learning in conjunction with STEAM was investigated by Sigit et al. (2022). The study's findings demonstrate how the PjBl-STEAM learning model improves students' comprehension of ecological ideas. However, because online learning prevented the assessment of student attitudes, this research has limitations in that area. According to research by Suprapto et al. (2023), STEAM-C integrated student worksheets can improve students' creative thinking abilities in plane material

While some previous studies have explored PjBL and its potential within the STEAM framework, there remains a dearth of research regarding PjBL-STEAM-based worksheets integrating eco-print techniques. Hence, further investigation into PjBL-STEAM-based worksheets concerning students' scientific reasoning and creativity, essential competencies for competing in the 21st century, is warranted. This study aims to bridge this gap due to the limited research available. The details of these instructional approaches are presented below.

Table 1. Syntax of PjBL on STEAM Student Worksheet Learning Activities

Learning Steps	Activities	STEAM
Asking physical questions in everyday life	• Praying • The teacher performs apperception with questions regarding the previous materials. • The teacher presents the theme and learning objectives.	
Problems' orientation	• The teacher and students determine the theme/topic of the project by putting forward guiding questions that direct students to determine a collaborative project. • The teacher provides instructions on the eco-print procedure based on the worksheet.	Science
Determining the project	• The teacher facilitates students to determine themes related to Spermatophyta. • The teacher asks students to prepare materials and tools for designing an eco-print project.	Science
Arranging Project plan	• The teacher facilitates students in designing the plans for completing the process and its management. • The teacher assists students in scheduling all the activities that have been carried out. • Teachers provide students with opportunities to access, manage, and search for information related to the eco-print projects.	Technology and Math
Monitor the students and the progress of the project	The teacher monitors students' activities in completing the design of the eco-print project made from simple materials based on the determined theme.	Engineering
Assessing the Outcome	The teacher facilitates students to prepare the final reports to be presented based on the creativity of each group.	Art
Evaluating the experience	The teacher and students reflect on the activities and results of the eco-print project assignments.	Science Engineering Art

Adapted from Robinson (2013); Jalinus et al. (2017); Nirmayani and Dewi (2021); Nurhidayah et al. (2021).

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Eco-print Technique

Using natural raw materials, the eco-print technique is a coloring method where the color absorbed combines with the fabric's color (Nurmasitah et al., 2022; Kasih et al., 2023). Direct color and shape transfer onto fabric is known as the eco-print technique. India Flint invented the eco-print dyeing method, which directly transfers color and shape to fabric (Bintrim, 2008). Because the materials for eco-print are easily obtained from the surrounding environment and the manufacturing technique is straightforward and does not require special machinery, it is beginning to be introduced to the general public (Kifti & Rahayu, 2022).

The eco-print technique has a positive impact on children as it not only enhances their creativity in creating artworks but also introduces them directly to various forms and types of leaves and flowers on plants through observation and tactile exploration, fostering the creation of unique pieces (Kasih et al., 2023). Participants can access a variety of plants to create eco-prints according to their imagination, allowing them to freely produce art using tools and materials, thereby facilitating independent learning through eco-print techniques to enhance naturalistic intelligence. Considering eco-print's role in assisting learners in understanding and cultivating creativity while appreciating eco-friendly art, its application extends beyond Indonesia to a global scale. Some studies conducted by Kasih et al. (2023) explored the implementation of eco-print techniques in enhancing naturalistic intelligence among children aged 4-6 years. Meanwhile, Ilyas et al. (2023) and Putri et al. 2023) examined the use of eco-print techniques to enhance creativity in early childhood. However, prior investigations have been limited in exploring the eco-print technique. Further research integrating this technique into student worksheets tailored to relevant models and approaches in 21st-century learning, such as PjBL-STEAM, is warranted.

Scientific Reasoning

Scientific reasoning refers to the abilities required to conduct scientific research, including making arguments, generating conclusions from data, and carrying out experiments (Zimmermann, 2005). Scientific reasoning ability is applying scientific principles, including problem identification, hypothesis formulation, prediction, problem-solving, experimentation, variable control, and data analysis (Ayuni et al., 2022). Students who follow scientific reasoning patterns can evaluate data or facts methodically and logically (Hadi et al., 2021). According to Ayuni et al. (2022), there are various aspects of scientific reasoning, including conservative reasoning, proportional reasoning, variable control, probability reasoning, correlation reasoning, and deductive hypothesis reasoning. Due to its connection to the competencies required for success in scientific research, scientific reasoning has gained widespread recognition as a fundamental element of STEM education. (Jamali et al., 2017).

Creativity

Creativity is a crucial skill in the 21st century, playing a pivotal role in preparing students to confront advancements in science and technology (Nurulwati et al., 2023). Teachers should support students' flexible mindsets, foster self-evaluation among students, and respond thoughtfully to students' feedback and questions (Kurniawati et al., 2022). Creativity is an individual's capacity to generate something unique and innovative with practical value, which constitutes the key to high-level thinking (Dinantika et al., 2019; Ajwar et al., 2021). Creativity yields novelty, utility, sustainability, and satisfaction for society (Sousa et al., 2012). In education, creativity is highly significant for comprehending a subject and attributing meaning to the activities to be undertaken (Ajwar et al., 2021). Students' creativity is associated with originality, novelty, and flexibility (Ummah et al., 2019). Creative students tend to explore new things, propose creative ideas, and collaborate with others to solve real-world problems (Weng et al., 2022).

Five primary components of creativity characterize the ability for creative thinking: the ability to generate many ideas (fluency), problem-solving using various methods (flexibility), originality, elaboration, and redefinition (Ajwar et al., 2021).

METHOD

This study's quasi-experimental nonrandomized control group pretest-posttest design was to ascertain whether project-based learning could be applied to STEAM-based students' worksheet analysis using the eco-print technique. Student creativity and scientific reasoning are the two dependent variables. Conversely, the learning model serves as the study's independent variable. The study was

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conducted in a public senior high school in Jakarta. Two classes of grade 10 MIPA students were included in the research sample. There were eighty students in each class, 35 females and 45 males. In the control class, students took lessons in the form of lectures, class discussions, and individual tasks, while in the experimental class, students followed learning through project-based learning on STEAM.

Table 2. Research Design

Group	Pretest	Independent Variable	Posttest
Experiment	Y1	X	Y2
Control	Y1	-	Y2

Description:
Y: Dependent variable before treatment
X: Independent variable (Using a project-based learning course on STEAM-based worksheet analysis using the eco-print technique)
Y2: Dependent variable after treatment

Scientific reasoning data were collected using the Lawson Classroom Test of Scientific Reasoning (LCTSR), which is an essay-based tool with 18 items. In addition, student creativity was assessed through a questionnaire and observation sheets. According to the framework established by Lawson in the LCTSR, the indicators for evaluating scientific reasoning include conservation reasoning, proportional reasoning, control of variables reasoning, probability reasoning, correlation reasoning, and hypothesis-deductive reasoning (Handayani et al., 2020). For creativity assessment, the indicators involved ideation and development, exploration of product design, interdisciplinary knowledge, appropriate material selection, and tool usage.

Analytical procedures involved ANCOVA testing. This inferential statistical analysis is used to test the research hypothesis. The data to be analyzed in this study are the results of the pre-test (students' initial abilities) as accompanying variables or covariates and the results of the post-test (students' social skills and self-confidence) as dependent variables. ANCOVA is a combination of regression with variance analysis used as a statistical control technique. Before ANCOVA, the research data's normality and homogeneity assumptions were verified through Shapiro-Wilk and Levene tests. Quade's Rank Analysis of Covariance was employed when the data failed to meet normality or homogeneity assumptions. Data analysis was executed using IBM Statistics 24 software, at the significance level of 5%.

RESULT AND DISCUSSION

The effectiveness of achieving these parameters can be impacted by the learning model used in the classroom. The results of the Shapiro-Wilk and Levene's tests for the data in this study are shown in Table 3. The significance levels for student scientific reasoning and creativity from the Shapiro-Wilk test are 0.704 and 0.562, respectively. Additionally, the significance levels from Levene's test are 0.454 and 0.622, respectively. This indicates that the data from this study meet the assumptions for normality and homogeneity.

Table 3. The Results of the Normality and Homogeneity Tests of the Research Data

Data	Statistical Tests	Sig.
Student scientific reasoning	Shapiro-Wilk test	0.704
	Levene's test	0.562
Student creativity	Shapiro-Wilk test	0.454
	Levene's test	0.622

According to the hypothesis test results shown in Table 4, the F-value was 39.586 at a significance level of lower than 0.05. This indicates that there was a significant difference in the levels of student scientific reasoning and creativity between the experimental class and the control class.

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Table 4. The Results of the ANCOVA Test

Data	Degree of Freedom	F	Sig.
Student scientific reasoning	1	27.427	< 0.05
Student creativity	1	16.327	< 0.05

The average scores of the adjusted results shown in Table 5 indicate that students in the experimental class achieved better learning outcomes than those in the control class (84.743> 72.628). This result indicates that students who received the integrated STEAM project-based learning and eco-print worksheet show much better learning outcomes than those who did not.

Table 5. The Comparison of Mean Scores of Corrected Results from Experimental and Control

Data	Classes	pretest	posttest	Increase (%)	Corrected Mean Scores
Student scientific reasoning	Experiment	54.683	84.246	53.584	84.743
	control	62.045	72.064	27.404	72.628
Student creativity	Experiment	69.843	85.546	37.324	82.573
	control	59.118	69.474	31.284	70.398

One of the parameters examined in this study is student scientific reasoning. The results of hypothesis testing using ANCOVA (Table 4) showed an F-value of 27.427 for the scientific reasoning variable with a significance level of less than 0.05. This indicates that students who engaged in project-based learning with STEAM-based worksheets exhibited a significant difference in their creative thinking skills compared to those who did not participate in this type of learning. Additionally, as shown in Table 5, the average score for scientific reasoning skills in the experimental group (84.743) was higher than that of the control group (72.628).

Another parameter examined is creative thinking. The hypothesis testing using ANCOVA (Table 4) yielded an F-value of 16.327 for the creative thinking skills variable, at a significance level of lower than 0.05. This indicates that students who participated in project-based learning with STEAM-based worksheets showed a significant improvement in their creative thinking skills compared to those who did not receive this type of instruction. Additionally, the data analysis presented in Table 5 reveals that the average score for creative thinking skills in the experimental group (82.573) was higher than that in the control group (70.398). These conclusions are based on the ANCOVA test results and the corresponding average scores.

The research findings exhibit a significant effect of project-based learning (PjBL) on STEAM-based student worksheets with eco-print techniques on students' scientific reasoning and creativity. In project-based learning, students are guided in creating eco-print projects using easily accessible materials relating to spermatophyte topics. This PjBL project is group-assigned, with learners initiating the project by selecting a specific topic with scaffolding guidance from the teacher. Students design the arrangement of plant parts used in batik eco-print results collaboratively based on their creativity. Within the PjBL, students collaborate and take responsibility as team members, recognizing the parallels between their learning and the surrounding environment. Engaging in this project allows students to enhance their abilities in discussing ideas, making predictions, and in collecting and analyzing data to address challenges, thereby refining their scientific reasoning skills.

Scientific reasoning involves a logical thought process to draw conclusions based on information. It is a systematic and logical thinking ability to solve problems using scientific methods (Handayani et al., 2020). Adequate teaching strategies, learning tools, and teachers' ability to foster an active learning environment are essential in nurturing students' scientific reasoning abilities (Handayani et al., 2020). Patterns of scientific reasoning enable students to logically and systematically analyze facts or information (Hadi et al., 2021). This capacity is vital for students to apply their acquired knowledge in resolving various encountered issues (Yulianti & Zhafirah, 2020). The ability to reason scientifically affects students' ease in resolving problems ((Develaki, 2017; Hejnová et al., 2018; Fawaiz et al., 2020).

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Scientific reasoning skills involve cognitive abilities to plan and conduct investigations (Lazonder, 2023).

This study's scientific reasoning assessment indicators encompass conservation reasoning, proportional reasoning, variable control reasoning, probability reasoning, correlation reasoning, and hypothesis-deductive reasoning (Handayani et al., 2020). Conservation reasoning involves students' ability to comprehend that specific properties of objects remain unchanged (Handayani et al., 2020). Correlation reasoning pertains to students' capability to determine the relationship between the studied phenomena. It involves creative thinking to identify mutual relationships between variables that play a role in hypothesis formulation and data interpretation (Hadi et al., 2021). Probability reasoning involves understanding various possibilities in an event and interpreting observation data (Hadi et al., 2021). Probabilistic reasoning is used to decide if the drawn conclusions have a probability of being true or false (Handayani et al., 2020). Proportional reasoning relates to students' ability to compare problem situations by enhancing students' sensitivity to deal with comparative situations (Hadi et al., 2021). Correlation reasoning concerns students' ability to determine relationships within the investigated phenomena. It identifies and determines reciprocal relationships between variables (Lawson, 2004). Variable control reasoning is students' ability to control certain variables in a given problem. Hypothesis-deductive reasoning involves students' ability to consider alternatives for specific situations. It encompasses the ability to form hypotheses from general theories followed by deduction to develop problem solutions (Han et al., 2016).

Integrating STEAM project-based learning is a facet of sound teaching practices (Sigit et al., 2022). The STEAM-PBL worksheets are crafted considering the steps of project-based learning and STEAM elements. These worksheets use projects as sources for students to discover knowledge and skills. Throughout the learning process, group discussion activities train students' scientific reasoning, enabling them to express their opinions among group members (Viyanti et al., 2023). Therefore, applying project-based learning on STEAM-based student worksheets with eco-print techniques positively enhances students' scientific reasoning compared to direct instruction.

Creativity is thinking and using imagination to produce something novel with utility. It becomes an essential skill for problem-solving in the learning process (Yeh & Ting, 2023). Creativity is a vital part of development among students. The growth of student creativity relies on how teachers foster it in the learning environment (Herak & Hadung Lamanepa, 2019). Thus, teachers must implement learning strategies that nurture students' creative thinking (Prajoko et al., 2023). STEAM is an educational approach providing students with opportunities to develop creativity, a crucial skill for the 21st century (Katz-Buonincontro, 2018); (Blackley et al., 2018).

Throughout the learning process, there is an emphasis on the five critical elements of STEAM. The science aspect pertains to the learning topic's content, while the technology aspect involves technology to explore information from various sources and the equipment for creating eco-prints. The technical aspect relates to students' ability to utilize eco-print techniques in designing products. The art aspect is crucial in fostering students' creativity in designing eco-print products, while the mathematical element helps students' capacity to use mathematical skills to determine the quantity and size of materials needed to design products. Including the art aspect in STEAM education is paramount in eliciting students' creativity in solving complex problems in the 21st century. The integration of art in STEAM fosters students' creativity and introduces interdisciplinary relationships through firsthand experiences gained during the learning process (Pearson, 2022).

STEAM makes learning more engaging and encourages students to express their creativity through visual arts, boosting their enthusiasm for science learning (Conradty & Bogner, 2020). Students achieve more relevant learning outcomes through the STEAM approach as they connect their learning with other fields of study, leading to a deeper understanding of the materials used in their projects (Herro et al., 2017). Leveraging technology has the potential to build learning interactions that prioritize active student participation in problem-solving activities (Irdalisa et al., 2020).

In addition to the STEAM approach, it is essential to integrate learning models with various disciplines and practical skills based on the needs of 21st-century education, where project-based learning (PjBL) emerges as a fitting model (Chiang & Lee, 2016; Miller et al., 2019). Hence, PjBL on STEAM-based student worksheets can serve as a platform for students to generate ideas based on science and technology through thinking and exploration in problem-solving by integrating science, technology, engineering, arts, and mathematics. This integration renders the learning process more

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meaningful for students and encourages them to identify issues and devise inventive solutions through the projects they work on, thereby nurturing their creativity. The results of Prajoko et al (2023) study show that the PjBL-STEM model affects students' creativity through problem-solving activities because they are directly involved in the learning process and produce creative products. The learning stages direct students to gain interesting and meaningful experiences where they construct their own knowledge through collaborative tasks and projects to produce authentic products.

STEAM has the potential to enhance students' creativity (Blackley et al., 2018; Rahman et al., 2020; Lu et al., 2022; Nabila & Kamaludin, 2023). PjBL on STEAM-based student worksheets with eco-print techniques focuses on ideation by linking various technological applications relevant to the subject matter with appropriate techniques, allowing students to create simple tools related to the lesson material (Irdalisa et al., 2023). Many straightforward projects undertaken by students enable them to learn more actively and solve everyday problems related to the studied topics (Deta & Widha, 2013). Using student worksheets as a support tool helps direct and enhance learning activities, leading to effective interaction between students and teachers. This worksheet is designed according to models and approaches, and it is relevant to the demands of 21st-century education.

Using this student worksheet can stimulate and develop students' abilities to generate creative ideas. Students can work creatively to develop ideas in creating a product within project-based learning (Viyanti et al., 2023). Alkautsar et al. (2023) demonstrate that STEM-PjBL worksheets can enhance collaboration skills, creativity, and computational thinking through structured learning activities. In implementing project-based learning on STEAM-based student worksheets with eco-print techniques, students are actively involved in the learning process and directed to learn through a project by following the instructional stages provided in the worksheets. Students collaborate with their group members regarding the design and completion of the eco-print project, gathering project-related information and seeking solutions to potential challenges encountered in project completion. These learning activities will hone students' creativity. Project-based learning allows students to learn and collaborate in solving problems. Thus, implementing project-based learning on STEAM-based student worksheets with eco-print techniques has a positive and effective impact on enhancing students' creativity compared to direct instruction.

CONCLUSION

In this research, the effect of project-based learning on STEAM-based student worksheet analysis with the eco-print technique shows significantly higher learning outcomes than the students in other classes. This research indicates that there is a better escalation of the learning outcome of the students who are taught using PjBL learning than those who have direct instruction, both on the parameters of students' scientific reasoning and creativity. The results of this research show that project-based learning on STEAM is an alternative form of learning relevant to the demands of the 21st century. It is recommended that applying PjBL-based STEAM against other parameters should be clarified in further studies to reveal other positive impacts of this model. Moreover, the learning duration should last longer to know the long-term impact of the developed model of the PjBL-based STEAM with the eco-print technique.

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