Research Article https://doi.org/10.12973/ijem.10.1.923

International Journal of Educational Methodology
Volume 10, Issue 1, 923 - 935.

ISSN: 2469-9632
https://www.ijem.com/

Effectiveness of Project-Based Learning on STEAM-Based student's worksheet analysis With Ecoprint Technique

Irdalisa*
Universitas Muhammadiyah Prof. DR. HAMKA, INDONESIA

Zulherman
Universitas Muhammadiyah Prof. DR. HAMKA, INDONESIA

Mega Elvianasti
Universitas Muhammadiyah Prof. DR. HAMKA, INDONESIA

Sri Adi Widodo
Universitas Sarjanawiyata Tamansiswa, INDONESIA

Erlia Hanum
Universitas Al Muslim, INDONESIA

Received: August 7, 2023 ▪ Revised: September 28, 2023 ▪ Accepted: November 10, 2023

Abstract: The objective of this research was to assess the efficacy of project-based learning in enhancing the analysis of student worksheets in the domains of Science, Technology, Engineering, Arts, and Mathematics (STEAM) with the integration of the ecoprint technique, focusing on its influence on student motivation and creativity. This investigation was conducted as a quasi-experiment involving a sample size of 150 students selected through cluster sampling. Data collection was executed using standardized tests, with instrument validity ascertained through the Aiken index and instrument reliability determined via Cronbach's alpha coefficient. Data analysis was performed using multivariate analysis (MANOVA) and descriptive quantitative methods. The study's findings reveal a significant disparity in the mean scores of both learning motivation and student creativity. In conclusion, the implementation of project-based learning coupled with STEAM-based student worksheet analysis utilizing the ecoprint technique yields a substantial enhancement in learning motivation and student creativity. These findings underscore the success of employing STEAM-based worksheets in conjunction with the ecoprint method to foster students' motivation and creativity, as ecoprint inherently encompasses all STEAM components within the manufacturing process.

Keywords: *Motivation, STEAM, student creativity, worksheet.*

To cite this article: Irdalisa, Zulherman, Elvianasti, M., Widodo, S. A., & Hanum, E. (2024). Effectiveness of project-based learning on STEAM-based student's worksheet analysis with Ecoprint technique. *International Journal of Educational Methodology*, *10*(1), 923-935. https://doi.org/10.12973/ijem.10.1.923

Introduction

The education field constantly evolves due to advancements in knowledge and technological innovation. The 21st century emphasizes student-centered learning to enhance skills (Patresia et al., 2020). Creativity is a required skill, which involves the mental process of generating original ideas (Dinantika et al., 2019). Students are trained to possess high levels of creativity to develop, enrich, and elaborate on ideas and solve problems from different perspectives (Harizah et al., 2021). The quality of education is always being improved so that students can have good skills to compete in the world of work. Efforts to develop learning models are always being developed to provide opportunities for teachers to provide effective learning. Project-based learning is one of the development models of learning that can be used in the learning process.

Creativity has become a focal point in the 21st century because it is highly needed to adapt to the advancements in science and technology. Learners who possess creativity can think critically and see problems from various angles, enabling them to have an open mindset when solving issues. Therefore, effective learning in schools occurs when there is a reciprocal communication between teachers and students. However, students often lack motivation, and their creativity remains undeveloped. They struggle to create something new and tend to imitate what they see. Many students also lack the initiative to solve problems. The creative potential an individual possesses represents a form of thinking that involves finding connections among existing elements or discovering new approaches to personal challenges. This is driven by a

* **Corresponding author:**
Irdalisa, Universitas Muhammadiyah Prof. DR. HAMKA, Jakarta, Indonesia. ✉ irdalisa@uhamka.ac.id

strong desire and motivation to create. The development of students' creativity tends to be slow due to their continued dependence on teachers.

The progress in nurturing students' creativity has been hindered by their persistent reliance on teachers for guidance and support (Teacher Center) (Irdalisa et al., 2023). The facilitation of student creativity can be effectively fostered through the deliberate choice of pedagogical models that demonstrate adaptability to the evolving demands of the globalized era. 21st-century learning models are aimed at student-centered learning, emphasizing inquiry-based activities (Rumahlatu & Sangur, 2019). The transition to student-centered learning allows students to develop their independence, engage in active exploration, work together, and take part in research projects. Students' ability to think critically can also be enhanced by practicum activities that concretize project learning (Telekova & Lukacikova, 2023). The application of Project-Based Learning (PBL) has been the subject of numerous studies. According to the findings, PBL has a favourable impact on students' motivation, engagement, and self-confidence (Condliffe et al., 2017). Muskania and Wilujeng's (2017) research demonstrates that PBL tools have a significant impact on students' scientific literacy.

Project-based learning facilitates student engagement in collaborative projects that encompass various subjects, offering them opportunities to delve into meaningful content exploration and collaborative experimentation (Belwal et al., 2020). The principles underpinning project-based learning underscore the development of students' problem-solving skills in authentic real-life scenarios (Zen et al., 2022). The process of creating products within PBL models empowers students to integrate and reconstruct their knowledge, fortify their professional competencies, heighten their interest, and refine their collaborative capabilities (Guo et al., 2020). The PBL underscores the importance of contextual learning through intricate activities, affording students the autonomy to explore and plan learning initiatives, engage in collaborative project execution, and ultimately yield tangible results (Adriyawati et al., 2020). For educators, project-based learning serves as a vehicle for refining their skills in meticulous project activity planning and preparation (Mansfield, 2023).

Project-Based Learning aligns seamlessly with the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. STEAM has emerged as a globally recognized approach for incorporating artistic components into the educational landscape (Jantassova et al., 2023). The fusion of project-based learning with STEAM elements exhibits a strong alignment with the competencies demanded in the 21st century (Lu et al., 2022). These 21st-century skills encompass creativity, critical thinking, inquisitiveness, problem-solving, logical reasoning, collaboration, and self-assurance, all of which can be effectively nurtured through the STEAM framework (Allina, 2018). STEAM-oriented learning empowers students to explore innovative and imaginative avenues for addressing challenges, presenting data, fostering innovation, and bridging diverse disciplines (Dyer, 2019). Artistry harmonizes with students' creative capacities and their ability to envision and innovate through technology, enabling the production of tangible creations and nurturing an artistic sensibility in their comprehension of science (Liu et al., 2023).

Within the realm of the learning process, the Student Worksheet emerges as a crucial pedagogical tool that significantly enhances the effectiveness of teaching and learning. The integration of Student Worksheets aids students in constructing their knowledge autonomously (Sa'adah & Ellianawati, 2022). In the context of science project laboratories, Suwarno et al. (2020) underscore the pivotal role of Student Worksheets in facilitating knowledge acquisition, reinforcing students' foundational competencies, and fostering active participation of both educators and learners in project-based activities. Science education places a premium on context, emphasizing the application of knowledge and experiences in the real world (Martawijaya et al., 2023). Consequently, it becomes imperative for educators to craft Student Worksheets in science learning, drawing upon established models, approaches, and methods. These worksheets serve to provide structured and focused learning activities, guiding students in their exploration of novel concepts. The development of Student Worksheets not only heightens student engagement but also shifts the learning paradigm from teacher-centric to learner centric (Melindawati, 2020). Therefore, in order to address the challenges of the 21st century, it becomes essential to redesign Student Worksheets that are thoughtfully tailored to incorporate biology concepts within the context of Science, Technology, Engineering, Arts, and Mathematics (STEAM).

Student Worksheets represent invaluable aids for facilitating and enriching learning experiences, fostering meaningful interactions between students and educators, and bolstering student motivation (Asnidar et al., 2016). Motivation constitutes a pivotal psychological factor within the realm of learning (Tasiwan et al., 2014). The presence of learning motivation holds paramount importance in the context of educational success, exerting a profound influence on students' educational progress and outcomes. Moreover, when educators opt for teaching models, they should take into account the characteristics inherent in the learning materials (Afriana et al., 2016). One particular area where students often encounter difficulties lies in their comprehension of spermatophytes, a topic encompassing the taxonomy and binomial nomenclature within the Plantae Kingdom. Students frequently struggle with memorizing the Latin language and navigating the hierarchical classification from Kingdom to Species. Furthermore, the vast array of plant types and species exacerbates the likelihood of errors in composing plant classifications and employing scientific nomenclature.

Field observations indicate that many Student Worksheets provided only contain material and tasks, making them appear dull and lacking in stimulating students' curiosity. Integrating student worksheets within the existing teaching models utilized in schools is not effectively implemented (Sa'adah & Ellianawati, 2022; Wandari et al., 2018). Teachers continue encountering difficulties in developing teaching materials, including creating Student Worksheets and assessment tools (Irdalisa et al., 2022). STEAM-based Student Worksheets are still rare, especially in Indonesian schools (Patresia et al., 2020).

One innovative and creative instructional medium based on STEAM that is relatively underutilized in education is Ecoprint. It is a method of decorating fabric using various plants to extract their natural colors (Setyaningrum & Purwanti, 2020). The ecoprint technique is employed in the study of Spermatophyta material. Ecoprint serves as an illustration of interdisciplinary education that combines art instruction with knowledge of leaf structure and identification. Therefore, this technique is well-suited for studying Spermatophyta material, which encompasses topics such as Classification (Taxonomy) and Scientific Nomenclature (Binomial Nomenclature) within the Kingdom Plantae (Plants). Ecoprint, as a learning medium, can enhance various skills possessed by students. During its creation process, ecoprint integrates all the elements of STEAM (Science, Technology, Engineering, Arts, and Mathematics). The ecoprint technique is relevant for integration with STEAM education because STEAM offers learners the opportunity to develop knowledge and skills through a series of activities that combine science, technology, engineering, art, and mathematics. This study aims to determine whether STEAM-based student worksheets that employ the ecoprint approach may increase student learning motivation and creativity.

Literature Review

Project-Based Learning (PBL)

The PBL model was developed by John Dewey, based on the concept of 'learning by doing,' which emphasizes direct experiential learning and student-centeredness (Maida, 2011). The analysis of previous research provides insights into the application of PBL in education. Mursid et al. (2022) conducted research on the blended project-based learning model's impact on creative thinking abilities. The findings suggest that creative thinking abilities need enhancement to ensure the effective implementation of the PBL model. Furthermore, this research focused on teaching engineering drawing, indicating the need for further studies on PBL in different subject areas. Syawaludin et al. (2022), in their study the PBL model in an online learning setting, explored its influence on students' analytical skills. The results indicate that in online learning design, the choice of project-based learning models can be effective when combined with the appropriate online learning settings, involving a combination of synchronous and asynchronous elements. Rahardjanto et al. (2019) conducted research on hybrid-PBL and its impact on learning outcomes and creative thinking skills. Their findings showed a significant influence on learning outcomes and creative thinking skills. However, there was no significant difference in learning motivation between the control group and the experimental group. Therefore, further research is needed to comprehensively understand the overall positive impact of this model. Suwarno et al. (2020) investigated the PBL model based on Student Worksheets (LKPD) and its influence on student competencies, especially creativity and applied science learning outcomes. The results demonstrated the impact of the PBL model based on LKPD on students' creativity and learning outcomes. However, effective planning, alignment of content, and time management are crucial. These results should be further developed in future research to gain insights into individual activities and their long-term effects.

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

STEAM, an acronym representing Science, Technology, Engineering, Arts, and Mathematics, embodies an interdisciplinary educational methodology designed to furnish students with the proficiencies necessary for thriving in the 21st century. It constitutes a contextual learning paradigm that interweaves diverse academic domains, prompting students to nurture a spectrum of abilities encompassing problem-solving, critical thinking, and collaborative skills (Sigit et al., 2022). The genesis of STEM (Science, Technology, Engineering, and Mathematics) in the United States was fundamentally driven by economic considerations, subsequently elevating STEM education as a focal point in both American and European contexts (Konkuş & Topsakal, 2022).

The integration of STEAM into education has emerged as a response to the increasing need to enhance students' interest and competence across these diverse fields. Alongside the implementation of STEAM, there arises a pressing need for an effective teaching model that can effectively bridge the gaps in academic knowledge. One particularly promising teaching model is PBL. It offers a dynamic and immersive approach to education, where students engage in real-world projects that require them to apply knowledge and skills from various disciplines. This makes PBL an ideal candidate for integration with interdisciplinary frameworks like STEAM. Several research studies have shed light on the potential of this integration. For instance. Konkuş and Topsakal (2022) conducted a study focused on the effects of STEAM-based activities on gifted students. The research yielded encouraging results, indicating a noticeable improvement in students' attitudes towards STEAM, their cooperative working skills, and even their career choices. However, it's worth noting that this study was conducted with a single sample group, prompting the need for further research that includes a control group. Another study by Martawijaya et al. (2023) explored the ethno-STEM PBL model and its impact on students' conceptual understanding. Their findings highlighted significant progress, marked by an enhancement in high-level thinking and a reduction in misconceptions among students. Siew and Ambo (2020) reported that students' creativity saw a marked increase when a STEM PBL learning approach was employed. This aligns with the idea that the hands on, inquiry-based nature of PBL can nurture creativity. Furthermore, Sigit et al. (2022) provided insights into how the integration of PBL with STEAM can significantly improve students' mastery of complex concepts, such as those found in ecology. While these studies have enriched our understanding of PBL and its potential within a STEAM framework, there remains an unexplored area PBL STEAM-based worksheets with the ecoprint technique. Hence, the researcher's intent is to adapt and assess the impact of worksheets based on PBL STEAM, incorporating the ecoprint technique to evaluate its influence on student motivation and creativity. In light of the limited research available on worksheets based on PBL STEAM and its effects on student motivation and creativity, this study seeks to address this gap, contributing to the growing body of knowledge in STEAM education.

Ecoprint Technique

Ecoprint can be performed using various methods, including boiling the fabric, pounding the plant material, or steaming the fabric (Pandasari et al., 2022). The ecoprint technique is commonly applied to natural fiber materials such as cotton, silk, canvas, and linen (Sedjati & Sari, 2019). The learning process places a strong emphasis on fostering the exploration of ideas through the integration of various technologies, art, and engineering applications that align with the subject matter. This approach enables students to acquire the skills needed to create simple tools relevant to the lesson content. Given that the ecoprint technique can be harnessed to help students grasp and appreciate environmentally friendly art by utilizing the natural environment, it holds applicability not only in Indonesia but also on a global scale. Ecoprint employs uncomplicated and user-friendly tools that can assist students in studying topics related to the plant kingdom. Irdalisa et al.'s (2023) research demonstrates that the integration of the ecoprint technique into STEAM-based worksheets serves as a highly suitable method for developing innovative learning resources that align with the requisites of the 21st century, placing a premium on the 4C skills: Critical thinking, collaboration, communication, and creativity. This study, up to this point, has primarily focused on assessing the validity, feasibility, and practicality of the STEAM-based worksheets developed using the ecoprint technique. However, it's important to acknowledge the scope of this research. Further investigation is warranted to comprehensively gauge the effectiveness of these STEAM-based worksheets with the ecoprint technique on student creativity and motivation. Consequently, the central research question pertains to the effectiveness of Project-Based Learning in conjunction with STEAM-based student's worksheet analysis utilizing the Ecoprint Technique on student motivation and creativity.

Methodology

Research Design

The primary objective of this research was to assess the effectiveness of Project-Based Learning when integrated with STEAM-based student's worksheet analysis using the Ecoprint Technique in enhancing students' learning motivation and creativity. To achieve this, a quasi experimental non equivalent control group design was employed to compare the changes in Learning Motivation and Student Creativity between the experimental group and the control group. In the experimental group, students received instruction through PBL within the context of STEAM-based student's worksheets while the control group underwent conventional learning methods. The details of these instructional approaches are presented in Table 1 below.

Table 1. Project-Based Learning Syntax Learning Activities

Learning steps	Activity	
	Educator	**Students**
Asking physical questions in everyday life	- Lead the prayer - Apperception by giving questions that have been studied before. - Convey the theme and learning objectives - Provide instructions on how to use ecoprint	- Pray together - Give answers to the teacher's questions - Listening and paying attention
Develop project planning	- Provide teaching materials - Provide assignments and instructions for group discussion activities.	Pay attention and carry out tasks
Doing independent learning	- - Provides an opportunity to seek information	· Access, manage, and communicate the information that has been obtained
Design in collaboration	- Provide opportunities to carry out activities - Controlling the course of activities	- Using engineering design - Solve the problem - Analyze ideas - Designing products

Table 1. Continued

Learning steps	Activity	
	Educator	**Students**
Test results	-Listening and assessing the presentation of the results of group activities - Reflecting on the results of the presentation of students - Provide opportunities for students to ask questions	- Testing and improving the results of the activities that have been carried out - Communicating results - Students actively ask questions about concepts they have not understood
Conduct an assessment	- Guiding students to conclude the learning that has been done - give post-test - provide post test results	- Summarize the material - Carrying out post tests

Sample and Data Collection

The research sample for this study comprised a total of 150 students, evenly divided into two groups with 75 students in each: the experimental group and the control group. Cluster sampling was employed as the sampling technique in this study. Cluster sampling was chosen because the sample members were drawn from a larger population, and the sampling process involved predetermined groups, as outlined in the methodology by Sugiyono (2015).

The assessment indicators for learning motivation encompassed attention, relevance, confidence, and satisfaction, as per the framework established by Afjar et al. (2020). Meanwhile, the assessment indicators for student creativity encompassed idea planning and development, exploration in product design, interdisciplinary knowledge, appropriate material selection, and tool usage. These questionnaires and observation sheets underwent a validation process conducted by experts in the field. To ascertain the validity of the research instrument, a panel of three educational experts conducted a validation process. This validation analysis aimed to determine the validity of the instrument items. The validation process involved assessing the level of expert agreement, as measured by the Aiken index (V). The empirical investigation of item validity can be conducted based on the measurement's objectives. In this research, the empirical investigation of items is carried out in the context of a formative test, making its validation follow the criteria-referenced test principles. Therefore, the test items can identify learning success, which is expressed in the formula for the item sensitivity index. When empirically investigating the item reliability of criterion-referenced tests, it should be expressed using the kappa index formula, as outlined by Subali (2019). The results of this measurement are presented in Table 2.

Table 2. Results of the Aiken Index Coefficient of Instrument Validity

Instrument	*V*	Information
learning motivation	.82	Valid
student creativity	.85	Valid

The reliability of the research instruments was assessed using Cronbach's alpha coefficient. The results indicated a high level of reliability for both instruments. Specifically, the reliability coefficient for the learning motivation test instrument was .82, and for the student creativity instrument, it was .85. These reliability values fall within the high-reliability category, as defined by Taber (2013).

Analyzing of Data

The study's data were analyzed using descriptive quantitative methods in SPSS version 22 for Windows. The normality of the data was assessed through the One-Sample Kolmogorov-Smirnov test, and the Levene test was used to check for homogeneity. Additionally, the MANOVA test was conducted to identify any significant differences in mean scores between the experimental and control groups.

Results

The effectiveness of the implementation of the STEAM-based Student Worksheets is determined based on the impact of applying on enhancing students' learning motivation and creativity. The difference in the average score between the experimental and the control class presented in Table 3 shows the average student's learning motivation and creativity. Both are higher than the average value in the control class.

Table 3. The comparison of the Average Value of Students' Learning Motivation and Creativity in Control and Experimental Class

Group	Aspect	Mean	Std. Deviation	*N*
Experimental Class	students' motivation	85.73	4.794	75
	creativity	83.93	2.448	75
Control Class	students' motivation	66.30	3.843	75
	creativity	68.93	2.196	75

This study seeks to assess the effectiveness of employing STEAM-based Student Worksheets alongside the ecoprint technique in enhancing students' learning motivation and creativity. The normality of the data was verified using the Kolmogorov-Smirnov test at a 5% significance level, confirming that the data followed a normal distribution. Similarly, the homogeneity test conducted with the Barlett test indicated that the samples were drawn from populations with equal variances. Based on the outcomes of the MANOVA test employing Wilk's Lambda analysis, an F value of 1008.423 was obtained, signifying statistical significance with a p-value < .05, which is less than the threshold of 0.05.

Table 4. Marginal Means and Cell Means

Class	Student Worksheet	Dependent Variable	Low	High
Experiment	Student Worksheet based on STEAM with ecoprint technique	Learning Motivation	70.79	86.58
		Student Creativity	80.00	93.00
Control	Conventional Student Worksheet	Learning Motivation	61.87	61.87
		Student Creativity	53.00	69.65
	Marginal Mean	Learning Motivation	66.33	74.23
		Student Creativity	66.5	81.33

In terms of students' learning motivation, those who utilized the STEAM-based Student Worksheet in conjunction with the ecoprint technique achieved an average score of 86.58. In contrast, those who utilized the conventional Student Worksheet obtained a mean score of 61.83. Therefore, the mean score for students' learning motivation was higher when using the STEAM-based Student Worksheet with ecoprint technique compared to the conventional Student Worksheet (Table 4). As for students' creativity, the mean score for those who used the STEAM-based Student Worksheet with ecoprint technique was 93.00, while for those who used the conventional Student Worksheet was 69.65. Furthermore, the mean score for creativity was significantly greater when utilizing the STEAM-based Student Worksheet with the ecoprint technique compared to the conventional Student Worksheet. Based on these findings, it can be conclusively affirmed that using STEAM-based Student Worksheets in conjunction with the ecoprint technique enhances students' learning motivation and creativity compared to conventional Student Worksheets. It may occur because the structure of the learning activities involving STEAM-based worksheets and the ecoprint technique places a strong emphasis on active participation. It encourages students to connect various aspects of knowledge, scientific skills, technology, engineering, art, and mathematics within the context of project-based work. Consequently, students become actively involved in exploration and collaboration throughout the project, which significantly influences their motivation and creativity.

Subsequent analyses were conducted to assess the distinctions in each factor concerning the dependent variables (Table 5). The results indicated a significant disparity in values (p-value < .05), leading to the conclusion that there were substantial variations in both learning motivation (p-value < .05) and student creativity (p-value < .05) between the experimental class and the control class. In summary, the application of Project-Based Learning in conjunction with STEAM-based student's worksheet analysis employing the Ecoprint Technique in the experimental class proved to be more effective in enhancing both Learning Motivation and Student Creativity compared to the conventional instructional model employed in the control class, as presented in Table 5.

Table 5. Test Result of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	F	Sig.
Corrected Model	learning motivation	1223.130	1	248.808	.000
	student creativity	1472.667	1	213.113	.000
Intercept	learning motivation	335278.241	1	68202.065	.000
	student creativity	339864.000	1	49182.545	.000
Group	learning motivation	1223.130	1	248.808	.000
	student creativity	1472.667	1	213.113	.000

Effect sizes along with statistical significance values That the significance value of students' learning motivation and creativity p-value < .001 (p < 0.05) which means that H0 is rejected and Ha which states that there is a difference in students' learning motivation and creativity scores simultaneously between the classes studied. with the STEAM-based Student Worksheet with the ecoprint technique compared to the conventional Student Worksheet is accepted. The effectiveness of applying PBL alongside STEAM-based student worksheets, utilizing the Ecoprint Technique in the experimental class, is attributed to the various stages of learning in which students engage. They are involved in project planning, self-directed learning, active exploration, and collaborative work. These learning activities provide students with opportunities to seek, manage, and communicate information acquired during the project's execution. Creative students, in particular, can produce intriguing and innovative products as a result.

Discussion

Students' learning motivation serves as a driving force for their learning activities. Student motivation can be enhanced by employing problem-solving techniques that establish a meaningful connection between the acquired knowledge and real-life circumstances. In project-based learning, students' motivation emerges through their experiences, collaboration, and authentic task construction. Students exhibit high perseverance in project completion, possess a high level of curiosity, participate actively, and work independently. The development of students' motivation aligns with the problem-solving process. Projects assigned can stimulate students' motivation as they learn and evaluate their projects, thereby generating satisfaction in the learning process. Students' motivation in learning can be enhanced through various models and approaches (Tasiwan et al., 2014).

The PBL model is an active learning approach that leverages real-world projects as a means of instruction. It is a practical and widely used innovation in education, where educators create learning experiences centered around everyday challenges to motivate students. By engaging in project-based learning, students are encouraged to explore, make choices, design, and ultimately produce a final product, thus enhancing their understanding and knowledge acquisition (Uziak, 2016). This learner-centered approach fosters meaningful learning as students seek relevant solutions and apply them in the context of project work (Chiang & Lee, 2016). By relating their learning to actual events, the PBL approach encourages students to acquire critical thinking skills, problem-solving techniques, and a deeper comprehension of subjects.

In the implementation of PBL, students collectively organize their knowledge by exploring various solutions to solve problems, there by fostering critical and creative thinking (Darling-Hammond et al., 2020; Han et al., 2016). According to Suradika et al. (2023), there are several principles in the PBL model: (a) students are at the center of the learning process; (b) the model enhances students' creativity; (c) it creates a challenging and enjoyable classroom environment; (d) the model incorporates values, aesthetics, ethics, sound reasoning, and kinesthetic learning; (e) it requires extended durations for sharing diverse learning experiences. These principles collectively contribute to the effectiveness of the PBL model in promoting student engagement and holistic development.

The integration of PBL with STEM has demonstrated its capacity to enhance students' learning motivation, establish meaningful learning encounters, and facilitate effective problem-solving (Tseng et al., 2013). Furthermore, collaborative group work during project development fosters cooperative attitudes, courage, and an openness to accepting others' perspectives. Heightened student motivation contributes to a more engaging learning process. Student Worksheets serve as catalysts in the learning journey, underscoring the importance of adhering to criteria for graphic media as visual aids to captivate students' interest (Saputro et al., 2019). PBL creates a conducive environment for applying skills, ultimately elevating the quality of the learning process and facilitating the attainment of higher cognitive levels by students (Yamin et al., 2017).

Creativity, defined as the capacity to generate something unique and innovative that holds practical value, represents a key facet of higher-level thinking, as highlighted by Dinantika et al. (2019). Throughout the learning process, students engage in project-based learning activities facilitated by teachers, with these projects aligning with the provided Student Worksheets. Student Worksheets play a pivotal role in fostering students' autonomy in the learning process and are meticulously crafted to align with specific learning competencies, as emphasized by Sari et al. (2019). Furthermore, Student Worksheets serve as valuable tools for nurturing students' independence, literacy, creativity, and comprehension, as underscored by Febriani et al. (2017).

The utilization of STEAM-based Student Worksheets in conjunction with the ecoprint technique affords students invaluable experiences and opportunities to craft their projects, drawing from both their subject matter knowledge and creative abilities. Ecoprint, as elucidated by Saraswati et al. (2019), represents a method of embellishing fabric through the utilization of naturally derived pigments sourced directly from plants, resulting in the creation of intricate and captivating patterns or motifs. Within the learning process, teachers play a guiding role, directing students in their project work by furnishing instructions that are intricately tied to the attainment of specific learning objectives.

These objectives emphasize the five key elements of STEAM. Students will plan by seeking various information about the given project's solution. At this stage, students engage in discussions with their group members regarding the design and project completion stages, gather information about solutions and potential challenges in project implementation, determine the maximum time required for project completion, and integrate STEAM components into the project being undertaken. Therefore, in completing project-based learning, students need to follow the stages outlined in the instructional materials and integrate STEAM into the topic. The integration of arts within STEAM enables teachers to assist students in becoming creative and recognizing interdisciplinary connections through hands-on experiences (Pearson, 2022).

The original conception of STEM, devised by the National Science Foundation, encompasses the amalgamation of Science (pertaining to the study of the natural world), Technology (centered on the examination of products designed to fulfill human needs), Engineering (involving the process of designing solutions to address problems), and Mathematics (serving as the language for comprehending shapes, numbers, and quantities) (DeCoito, 2014). Subsequently, STEM expanded into STEAM through the inclusion of "Arts." This augmentation allows learners to showcase their creativity, effectiveness, fiscal acumen, and artistic prowess in the context of resolving real-world challenges (Razi & Zhou, 2022). Additionally, it enriches employability skills, fostering attributes such as teamwork, communication, and adaptability (Colucci-Gray et al., 2017).

Georgette Yakman's notion for STEAM first surfaced in the early 2000s, and it grew in acceptance by the mid-2000s (Pearson, 2022). It was first made available in the US in 2007 (Daugherty, 2013). The STEAM method stimulates student creativity and collaboration more than it does academic strategy (Belbase et al., 2022; Liao, 2019). It is a disruptive innovation in education. Students actively participate in the learning process and acquire 21st-century abilities when using the STEAM approach. Taylor (2016) highlights the following crucial STEAM components: (a) STEAM strengthens and broadens the scope of STEM; (b) STEAM enables science teachers to participate in the development of school-based curricula; (c) STEAM incorporates teachers in the process of building a student-centered vision of 21st-century education; and (d) STEAM offers a way to integrate the arts and humanities into STEM instruction.; (e) STEAM initiatives can be crafted and executed by individual educators on a manageable scale.; (f) Educators have the capacity to develop STEAM activities within the framework of project-based learning. In STEAM education, instructional models often incorporate collaborative or cooperative learning approaches, wherein students take on the role of subject matter experts and collaborate within groups to collectively complete tasks (Edelen et al., 2023; Thompson et al., 2020).

STEAM broadens students' outlook on the issues at hand and motivates them to seek resolutions (Pearson, 2022). The application of diverse critical and creative thinking techniques to pertinent curriculum content serves as a catalyst for motivating students to actively participate in critical and purposeful discussions regarding the subjects they are studying. Students become better equipped to identify problems and devise inventive solutions through habitual application of these techniques. They also gain confidence in sharing their findings and concepts with others.

Implementing the STEAM-based Student Worksheet with the ecoprint technique demonstrates a substantial impact and effectiveness in enhancing students' creativity. This efficacy is attributed to the emphasis on creativity-enhancing learning within the PBL STEAM model. STEAM integrates two thinking models that cultivate talent by integrating interdisciplinary skills and creativity (Lu et al., 2022). PBL integrated with the STEAM approach is applied in learning, resulting in the creation of a product by applying STEAM principles to project development (Adriyawati et al., 2020).

During the implementation phase, the utilization of STEAM-based Student Worksheets with the ecoprint technique promotes the seamless integration of content across diverse subjects encompassing science, technology, art, and mathematics. The science elements related to the learning content; the technological aspects of using the internet to browse information from numerous sources on the equipment and supplies required to create ecoprints; the scientific components related to the learning content; the technical component concerns how well students can use the ecoprint technique to design products; the artistic component concerns how well students can use their creativity to design ecoprints to produce interesting results; and the mathematical component focuses on how well students can use mathematical analysis to determine the quantity and size of materials required to create ecoprints. The presence and specifications of technology, along with its supportive applications, have the potential to establish novel learning interactions that prioritize active participation and offer direct learning encounters, thereby stimulating student engagement in problem-solving, as highlighted by Irdalisa et al. (2020).

Within the sequence of PBL integrated with STEAM, students are actively immersed in the learning process by amalgamating knowledge and skills. This integration serves as a conduit for students to acquire enriching learning experiences and refine their creative aptitude. As students embark on project-based activities, they are guided to exercise creativity in their planning and product design, drawing from the concepts they have assimilated. Creativity, as Dinantika et al. (2019) elucidate, represents an experiential journey through which individuals express themselves and generate valuable ideas, thoughts, and actions.

Thus, the results of this research represent an innovation in designing student's worksheets that are tailored to the needs of students, thereby enhancing their engagement and learning activities through project-based assignments. This, in turn, contributes to their mastery of competencies. These worksheets are designed in accordance with a model and approach that aligns with the 21st-century learning paradigm. The development of STEAM-based LKPDs with the ecoprint technique can serve as a benchmark for educators when redesigning their own worksheets, fostering creativity and innovation. Moreover, utilising worksheets must consider the characteristics of the subject matter to meet the diverse learning needs of students. Given the infrequent use of STEAM-based worksheets like this, they can be valuable in teaching and learning.

The implementation of STEAM-based student's worksheets with the ecoprint technique in biology education represents an innovative approach to enhancing student creativity and motivation. The theoretical findings from this research can serve as a reference and source of knowledge for educators and educational practitioners, especially in the development of innovative worksheets. Teachers can employ these worksheets as alternative learning media in their teaching process. For students, using these worksheets helps nurture creativity and motivation in the learning process. STEAM-based student worksheets with the ecoprint technique sharpen and develop students' skills in generating creative ideas and concepts, particularly during ecoprint-related projects. Students are guided and supported throughout the project, emphasising the five key elements of STEAM. Teachers can utilize these worksheets as supportive tools in the teaching and learning process, fostering optimal interaction between educators and students.

Previous research has consistently demonstrated that the STEAM learning approach has a profound impact on students' knowledge competencies and significantly enhances their creativity, as evidenced by the studies conducted by Arsy and Syamsulrizal (2021). Furthermore, multiple research findings have underscored the capacity of STEAM to foster the development of advanced thinking skills, promote collaboration, encourage argumentation, and stimulate student creativity, as highlighted by Afriana et al. (2016). Leveraging PBL serves as an effective strategy for involving students in STEAM learning, thereby affording them opportunities to cultivate and apply their creative abilities, as suggested by the research conducted by Siew and Ambo (2020). In the project planning phase, selecting activities by integrating various materials tailored to accessible tools and resources helps enhance student creativity compared to conventional learning. Elaboration, related to the ability to develop ideas and specify details of an object or concept, represents one characteristic of creativity. PBL enhances students' knowledge and skills (Ralph, 2015). PBL emphasizes long-term and interdisciplinary learning (Hawari & Noor, 2020). Therefore, using STEAM-based Student Worksheets with ecoprint technique will engage students actively in learning by fostering innovation through group discussions that combine various elements of STEAM. This approach is effective in enhancing students' learning motivation and creativity.

Conclusion

Based on the research findings, it can be deduced that using STEAM-based Student Worksheets in conjunction with the ecoprint technique effectively enhances both students' learning motivation and creativity. Those students who were exposed to the STEAM-based Student Worksheets with the ecoprint technique demonstrated superior levels of learning motivation and creativity compared to their peers who relied on conventional Student Worksheets. Consequently, STEAM-based worksheets incorporating the ecoprint technique serve as a promising avenue for creating innovative learning resources that align seamlessly with the contemporary demands of the 21st century. Educators are encouraged to harness the potential of STEAM-based Student Worksheets integrated with the ecoprint technique as a pioneering tool in the realm of biology education, leveraging its capacity to nurture students' creativity and motivation. Acknowledging the diverse array of topics, learning motivations, and preferences among students, biology instructors should explore and implement various student-centric instructional models. It is important to note that this research possesses a limitation in that the development of PBL and STEAM-based worksheets with the ecoprint technique was restricted to the specific subject matter of Spermatophyta.

Recommendations

Researchers suggest that research using Project-Based Learning on STEAM-Based student's worksheet analysis with Ecoprint Technique can involve a larger number of samples. In addition to the above, this study could be expanded to encompass other techniques or subjects, aligning with the subject-specific objectives. The researcher recommends that the impact of PBL on STEAM-Based student's worksheet analysis with the Ecoprint Technique be further explored through a qualitative approach, specifically employing post-teaching and learning sessions interviews with students who have experienced this method. For future research endeavors, it is imperative to emphasize the pursuit of meaningful investigations in alignment with the objectives of self-learning curricula. Moreover, there is a pressing need for additional studies focused on PBL-STEAM-based worksheets, given their limited integration within teaching and learning contexts. The results of this research can be used by teachers to help design innovative student worksheets as a means to facilitate the learning process and enhance student engagement, particularly in biology education, thereby improving students' competence.

Limitations

This research is limited to increasing students' creative abilities and learning motivation. Other than that, it is limited to ecoprint material.

Acknowledgments

Our thanks to "The Research and Development Board of PP Muhammadiyah and the Research Institute of Universitas Muhammadiyah Prof. Dr Hamka" for funding this research through the RISETMU grant the number 1687.045/PP/I.3/D/2022, Unit Pembina Publikasi Ilmiah (UPPI) Universitas Muhammadiyah Prof. DR. HAMKA Jakarta, Indonesia, for supporting this study.

13

Conflict of Interest

The authors declare no conflict of interest.

Authorship Contribution Statement

Irdalisa: Conceptualization and design. Zulherman: Editing/reviewing, supervision. Elvianasti: Analysis. Widodo: Critical revision of manuscript. Hanum: Data analysis

References

Adriyawati, Utomo, E., Rahmawati, Y., & Mardhiah, A. (2020). STEAM-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning. *Universal Journal of Educational Research*, *8*(5), 1863-1873. https://doi.org/10.13189/ujer.2020.080523

Afjar, A. M., Musri, & Syukri, M. (2020). Attention, relevance, confidence, satisfaction (ARCS) model on students' motivation and learning outcomes in learning physics. *Journal of Physics: Conference Series*, *1460*, Article 012119. https://doi.org/10.1088/1742-6596/1460/1/012119

Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project based learning integrated to STEM to enhance elementary school's students scientific literacy. *Journal of Indonesian Science Education /Jurnal Pendidikan IPA Indonesia, 5*(2), 261-267. https://bit.ly/3ZWH1Kc

Allina, B. (2018). The development of STEAM educational policy to promote student creativity and social empowerment. *Arts Education Policy Review*, *119*(2), 77-87. https://doi.org/10.1080/10632913.2017.1296392

Arsy, I., & Syamsulrizal. (2021). Pengaruh pembelajaran STEAM (Science, Technology, Engineering, Art and mathematics) terhadap kreativitas peserta didik [The influence of STEAM learning (Science Technology, Engineering, Arts, and Mathematics) on student creativity]. *Biolearning Jurnal,* 8(1), 24-26. https://doi.org/10.36232/jurnalbiolearning.v8i1.1019

Asnidar, Hala, Y., & Yaiyeb, A. M. (2016). Pengaruh penggunaan lembar kerja peserta didik berbasis peta konsep terhadap motivasi dan hasil belajar peserta didik kelas VII SMPN 1 Awangpone [The influence of using concept map-based student worksheets on the motivation and learning outcomes of class VII students at SMPN 1 Awangpone]. *Jurnal Bionature*, *17*(2), 102-106. https://ojs.unm.ac.id/bionature/article/view/2839

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., & Jarrah, A. (2022). At the dawn of science, technology, engineering, arts and mathematics (STEAM) education: Prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology, 53*(11), 2919-2955. https://doi.org/10.1080/0020739X.2021.1922943

Belwal, R., Belwal, S., Sufian, A. B., & Al Badi, A. (2020). Project-based learning (PBL): Outcomes of students' engagement in a external consultancy project in Oman. *Education and Training, 63*(3), 336-359. https://doi.org/10.1108/ET-01-2020-0006

Chiang, C. L., & Lee, H. (2016). The effect of project-based learning on learning motivation and problem-solving ability of vocational high school students. *International Journal of Information and Education Technology*, *6*(9), 709-712. https://doi.org/10.7763/IJIET.2016.V6.779

Colucci-Gray, L., Trowsdale, J., Cooke, C. F., Davies, R., Burnard, P., & Gray, D. S. (2017). *Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21 st learning: How can school curricula be broadened towards a more responsive, dynamic and inclusive form of education?* British Educational Research Association. http://doi.org/10.13140/RG.2.2.22452.76161

Condliffe, B., Quint, J., Visher, M. G., Bangser, M. R., Drohojowska, S., Saco, L., & Nelson, E. (2017). *Project-based learning a literature review* (Workng Paper). MDRC. https://bit.ly/41MaQy4

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Daugherty, M. K. (2013). The prospect of an "A" in STEM education. *Journal of STEM Education: Innovations and Research*, *14*(2), 10–15. https://bit.ly/3M5iwVt

DeCoito, I. (2014). Focusing on science, technology, engineering, and mathematics (STEM) in the 21st century. *Ontario Professional Surveyor*, *57*(1), 34-36. https://shorturl.at/dfiuC

Dinantika, H. K., Suyanto, E., & Nyeneng, I. D. P. (2019). Pengaruh penerapan model pembelajaran project-based learning terhadap kreativitas siswa pada materi energi terbarukan [The effect of applying the project-based learning model on student creativity in renewable energy material]. *Titian Ilmu: Jurnal Ilmiah Multi Sciences, 11*(2), 73-80. https://doi.org/10.30599/jti.v11i2.473

Dyer, M. (2019). STEAM without hot air: Strategy for educating creative engineers. *Australasian Journal of Engineering Education, 24*(2), 74-85. https://doi.org/10.1080/22054952.2019.1693122

Edelen, D., Cox, R., Bush, S. B., & Cook, K. (2023). Centering student in transdisciplinary STEAM using positioning theory. *The Electronic Journal for Research in Science and Mathematics Education*, *26*(4), 111-129. https://ejrsme.icrsme.com/article/view/21861

Febriani, S., Sudomo, J., & Setianingsih, W. (2017). Development of student worksheet based on problem based learning approach to increase 7th grade student's creative thinking skills. *Journal of Science Education Research*, *1*(1), 1-4. https://doi.org/10.21831/jser.v1i1.16179

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research, 102,* Article 101586. https://doi.org/10.1016/j.ijer.2020.101586

Han, S., Rosli, R., & Capraro, M. M., & Capraro, R. M. (2016). The effect of science, technology, engineering, and mathematics (STEM) project-based learning (PBL) on students' achievement in four mathematics topics. *Journal of Turkish Science Education*, *13*, 3-29. https://bit.ly/3rX7afx

Harizah, D. T. D., Sumarni, & Bachri, S. (2021). Pengaruh model pembelajaran project-based learning terhadap kreativitas dan hasil belajar geografi siswa [The influence of the project-based learning model on students' creativity and geography learning outcomes]. *Journal of Education: Theory, Research, and Development /Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan, 6*(5), 767-771. https://bit.ly/3M5NBIS

Hawari, A. D. M., & Noor, A. I. M. (2020). Project based learning pedagogical design in STEAM art education. *Asian Journal of University Education*, *16*(3), 102-111. http://doi.org/10.24191/ajue.v16i3.11072

Irdalisa I., Akbar, B., Amirullah, G., Fuadi, T. M., Elvianasti, M., & Safahi, L. (2022). Implementation of moodle platform to acquire the students' knowledge and science process skills. *Cypriot Journal of Educational Sciences, 17*(9), 3238-3247. https://doi.org/10.18844/cjes.v17i9.7349

Irdalisa, I., Amirullah, G., Hanum, E., Elvianasti, M., & Maesaroh. (2023). Developing STEAM-based students' worksheet with the ecoprint technique in biology subject. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran, 9*(1), 132-139. https://doi.org/10.33394/jk.v9i1.6775

Irdalisa, Paidi, & Djukri. (2020). Implementation of technology-based guided inquiry to improve TPACK among prospective biology teachers. *International Journal of Instruction*, *13*(2), 33-44. https://doi.org/10.29333/iji.2020.1323a

Jantassova, D., Hockley, A. D., Shebalina, O., & Akhmetova, D. (2023). Evaluation of communication and collaboration processes for creating an integrative STEAM space at the Saginov Technical University. *TEM Journal, 12*(1), 470-481. https://doi.org/10.18421/TEM121-57

Konkuş, O. C., & Topsakal, U. U. (2022). The effects of STEAM-based activities on gifted students' STEAM attitudes, cooperative working skills and career choices. *Journal of Science Learning*, *5*(3), 395-410. https://doi.org/10.17509/jsl.v5i3.46215

Liao, C. (2019). Creating a STEAM map: A content analysis of visual art practices in STEAM education. In M. S. Khine, & S. Areepattamannil (Eds.), *STEAM education: Theory and Practice* (pp. 37-55). Springer. https://bit.ly/46z4941

Liu, C.-Y., Wu, C.-J., Chien, Y.-H., Tzeng, S.-Y., & Kuo, H.-C. (2023). Examining the quality of art in STEAM learning activities. *Psychology of Aesthetics, Creativity, and the Arts, 17*(3), 382-393. https://doi.org/10.1037/aca0000404

Lu, S.-Y., Lo, C.-C., & Syu, J.-Y. (2022). Project based learning oriented STEAM: The case of micro-bit paper-cutting lamp. *International Journal of Technology and Design Education, 32*, 2553-2575. https://doi.org/10.1007/s10798-021-09714-1

Maida, C. A. (2011). Project-based learning: A critical pedagogy for the twenty-first century. *Policy Future in Education*, *9*(6), 759-768. https://doi.org/10.2304/pfie.2011.9.6.759

Mansfield, J. (2023). Supporting the development of pre-service teachers' pedagogical knowledge about planning for practical work. *Journal of Science Teacher Education,* *34*(3), 225-247. https://doi.org/10.1080/1046560X.2022.2042979

Martawijaya, M. A., Rahmadhanningsih, S., Swandi, A., Hasyim, M., & Sujiono, E. H. (2023). The Effect of Applying the ethno-STEM-project-based learning model on students' higher-order thinking skill and misconception of physics topics related to Lake Tempe, Indonesia. *Journal of Indonesian Science Education/ Jurnal Pendidikan IPA Indonesia, 12*(1), 1-13. https://doi.org/10.15294/jpii.v12i1.38703

Melindawati, S. (2020). Development of integrated thematic student worksheets (LKPD) using the discovery learning model in class IV Elementary Schools. *International Journal of Educational Research and Social Sciences*, *1*(1), 7-15. https://doi.org/10.51601/ijersc.v1i1.4

Mursid, R., Saragih, A. H., & Hartono, R. (2022). The effect of the blended project-based learning model and creative thinking ability on engineering students' learning outcomes. *International Journal of Education in Mathematics, Science, and Technology, 10*(1), 218-235. https://doi.org/10.46328/ijemst.2244

Muskania, R. T., & Wilujeng, I. (2017). Pengembangan perangkat pembelajaran project-based learning untuk membekali foundational know-ledge dan meningkatkan scientific literacy [Development of project-based learning learning tools to provide foundational knowledge and improve scientific literacy]. *Cakrawala Pendidikan*, *36*(1), 34-43. https://doi.org/10.21831/cp.v36i1.8830

Pandasari, P., Purwanti, R., & Alfianti, D. A. (2022). Analysis of steaming ecoprint techniques on various fabrics. *Formosa Journal of Social Sciences, 1*(4), 411-424. https://doi.org/10.55927/fjss.v1i4.2049

Patresia, I., Silitonga, M., & Ginting, A. (2020). Developing biology students' worksheet based on STEAM to empower science process skills. *Jurnal Pendidikan Biologi Indonesia, 6*(1), 147-156. https://bit.ly/3uZDOOD

Pearson, R. (2022). STEAM education and the whole child: Examining policy and barrriers. *International Journal of The Whole Child, 7*(2), 109-120. https://bit.ly/3S476Fy

Rahardjanto, A., Husamah, & Fauzi, A. (2019). Hybrid-PBL: Learning outcomes, creative thinking skills, and learning motivation of preservice teacher. *International Journal of Instruction, 12*(2), 179-192. https://doi.org/10.29333/iji.2019.12212a

Ralph, R. A. (2015). Post secondary project-based learning in science, technology, engineering and mathematics. *Journal of Technology and Science Education, 6*(1), 26-35. https://doi.org/10.3926/jotse.155

Razi, A., & Zhou, G. (2022). STEM, iSTEM, and STEAM: What is next? *International of Technology in Education*, *5*(1), 1-29. https://doi.org/10.46328/ijte.119

Rumahlatu, D., & Sangur, K. (2019). The influence of project-based learning strategies on the metacognitive skills, concept understanding and retention of senior high school students. *Journal of Education and Learning*, *13*(1), 104-110. https://doi.org/10.11591/edulearn.v13i1.11189

Sa'adah, U., & Ellianawati. (2022). Pengembangan students worksheet online berbasis STEAM pada materi fluida dinamis untuk meningkatkan kreativitas peserta didik [Development of STEAM-based online students' worksheets on dynamic fluid material to increase students' creativity]. *Unnes Physics Educational Journal, 11*(1), 44-53. https://bit.ly/47oaH5d

Saputro, R., Setiawan, D., & Saragih, D. (2019). The development of students worksheet (SW) based on inquiry to improve activity and learning outcomes in civic lesson of students grade VII. In E. L. Damanik, M. R. Damanik, & R. Rahim (Eds.), *Proceedings of the 1st International Conference on Social Sciences and Interdisciplinary Studies* (*ICSSIS 2018*) (pp. 299-304). Atlantis Press. https://doi.org/10.2991/icssis-18.2019.62

Saraswati, R., Susilowati, M. H. D., Restuti, R. C., & Pamungkas, F. D. (2019). *Pemanfaatan daun untuk ecoprint dalam menunjang* pariwisata [Utilization of leaves for ecoprints to support tourism]. Departemen Geografi FMIPA Universitas Indonesia.

Sari, Y. S., Selisne, M., & Ramli, R. (2019). Role of students worksheet in STEM approach to achieve competence of physics learning. *Journal of Physics: Conference Series, 1185,* Article 012096. https://doi.org/10.1088/1742-6596/1185/1/012096

Sedjati, D. P., & Sari, V. T. (2019). Mix teknik ecoprint dan teknik batik berbahan warna tumbuhan dalam penciptaan karya seni tekstil [Mix ecoprint techniques and batik techniques made from plant colors in the creation of works of art]. *Corak*, *8*(1), 1-11. https://bit.ly/3RZZRhG

Setyaningrum, F., & Purwanti, S. (2020). Ecoprint batik making training as a science learning media for elementary school teachers at PCM Berbah. *National Seminar on Results of Community Service/Seminar Nasional Hasil Pengabdian kepada Masyarakat, 2*, 79-88. https://bit.ly/46URzf5

Siew, N. M., & Ambo, N. (2020). The scientific creativity of fifth graders in a STEM project-based cooperative learning approach. *Problem of Education in the 21th Century, 78*(4), 627-643. https://doi.org/10.33225/pec/20.78.627

Sigit, D. V., Ristanto, R. H., & Mufida, S. N. (2022). Integration of project-based e-learning with STEAM: An innovative solution to learn ecological concept. *International Journal of Instruction*, *15*(3), 23-40. https://doi.org/10.29333/iji.2022.1532a

Subali, B. (2019). *Prinsip asesmen dan evaluasi pembelajaran*, *Edisi Ketiga*. UNY Press.

Sugiyono. (2015). *Metode penelitian kombinasi (Mixed methods)* [Combination research methods (Mixed methods)]. Alfabeta.

Suradika, A., Dewi, H. I., & Nasution, M. I. (2023). Project-based learning and problem-based learning models in critical and creative students. *Journal of Indonesian Science Education/Jurnal Pendidikan IPA Indonesia, 12*(1), 153-167. https://doi.org/10.15294/jpii.v12i1.39713

Suwarno, S., Wahidin, & Nur, S. H. (2020). Project-based learning model assisted by worksheet: It's effect on students' creativity and learning outcomes. *Jurnal Pendidikan Biologi Indonesia*, *6*(1), 113-122. https://bit.ly/3NSsRFr

Syawaludin, A., Prasetyo, Z. K., Jabar, C. S. A., & Retnawati, H. (2022). The effect of project-based learning model and online learning setting on analytical skills of discovery learning, interactive demonstrations, and inquiry lessons. *Journal of Turkish Science Education*, *19*(2), 608-621. https://bit.ly/46z05kh

Taber, K. S. (2013). Ken Springer: Educational research: A contextual approach. *Science and Education Journal*, *22*, 1267–1279. https://doi.org/10.1007/s11191-011-9420-x

Tasiwan, Nugroho, S. E., & Hartono. (2014). Analysis of the level of student motivation in learning science with the project-based advance organizer model. *Journal of Indonesian Science Education/ Jurnal Pendidikan IPA Indonesia, 3*(1), 43-50. https://bit.ly/3S4he0m

Taylor, P. C. (2016). Why is STEAM curriculum perspective crucial to the 21st century? In *Proceedings of the Research Conference 2016* (pp. 89-93). Australian Council for Educational Research (ACER). https://bit.ly/3SkiIo3

Telekova, R., & Lukacikova, R. S. (2023). The intellectual assumptions and critical thinking in preparing a child for school education. *TEM Journal*, *12*(2), 721-725. https://doi.org/10.18421/TEM122-15

Thompson, K., Chapman, S. N., & Kanasa, H. (2020). Tools to mediate learning and self-assessment in a STEAM unit of work. In K. Tomas, & D. Huffman (Eds.), *Challenges and opportunities for transforming from STEM to STEAM education* (pp. 24-50). IGI Global. https://doi.org/10.4018/978-1-7998-2517-3.ch002

Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PBL) environment. *International Journal Technology and Design Education, 23*, 87-102. https://doi.org/10.1007/s10798-011-9160-x

Uziak, J. (2016). A project-based learning approach in an engineering curriculum. *Global Journal of Engineering Education*, *18*(2), 119-123. https://bit.ly/3S2saMj

Wandari, A., Kamid, & Maison, M. (2018). Pengembangan lembar kerja peserta didik (LKPD) pada materi geometri berbasis budaya jambi untuk meningkatkan kreativitas siswa [Development of student worksheets (LKPD) on geometry material based on Jambi culture to increase student creativity]. *Edumatika: Jurnal Riset Pendidikan Matematika, 1*(2), 47-55. https://doi.org/10.32939/ejrpm.v1i2.232

Yamin, Y., Permanasari, A., Redjeki, S., & Sopandi, W. (2017). Application of model project-based learning on integrated science in water pollution. *Journal of Physics: Conference Series, 895*, Article 012153. https://doi.org/10.1088/1742-6596/895/1/012153

Zen, Z., Reflianto, Syamsuar, & Ariani, F. (2022). Academic achievement: The effect of project-based learning method and student engagement. *Heliyon*, *8*(11), Article e11509. https://doi.org/10.1016/j.heliyon.2022.e11509

IJEM_10_1_923_1_2.pdf

ORIGINALITY REPORT

15%	12%	10%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	ejournal.umm.ac.id Internet Source	1%
2	Kapambwe Mwelwa, Ailwei Ailwei, S. Mawela. "Effectiveness of Internships as Pedagogical Practices in Promoting Employability Skills Amongst Graduating Students in Selected Social Science Degree Programmes in Zambia", International Journal of Educational Methodology, 2021 Publication	<1%
3	ejournal.upi.edu Internet Source	<1%
4	Okan Yolcu. "An Examination of Instructional Autonomy Practices of Science Teachers", International Journal of Educational Methodology, 2021 Publication	<1%
5	Gufron Amirullah, Irdalisa Irdalisa. "Mastery of STEM-Based Research Approach of Science Teachers In Jakarta", AL-ISHLAH: Jurnal Pendidikan, 2022	<1%

Publication

6	jurnal.ar-raniry.ac.id Internet Source	<1%
7	Ellin Carlina, , Djukri. "Science Project-based Learning Integrated with Local Potential to Promote Student's Environmental Literacy Skills", Advanced Journal of Social Science, 2018 Publication	<1%
8	bspace.buid.ac.ae Internet Source	<1%
9	Submitted to The University of Texas at Arlington Student Paper	<1%
10	erl.ucc.edu.gh:8080 Internet Source	<1%
11	edusimsteam.eba.gov.tr Internet Source	<1%
12	journal.lppmunindra.ac.id Internet Source	<1%
13	dm.saludcyt.ar Internet Source	<1%
14	ijte.net Internet Source	<1%
15	index.j-ets.net Internet Source	

		<1%
16	www.journal.staihubbulwathan.id Internet Source	<1%
17	repository.lppm.unila.ac.id Internet Source	<1%
18	goldenratio.id Internet Source	<1%
19	ijmmu.com Internet Source	<1%
20	www.e-iji.net Internet Source	<1%
21	www.ejmste.com Internet Source	<1%
22	ijlter.org Internet Source	<1%
23	tused.org Internet Source	<1%
24	journal.unnes.ac.id Internet Source	<1%
25	jurnalfkip.unram.ac.id Internet Source	<1%
26	Submitted to Middle East Technical University Student Paper	<1%

27	"The Wiley Handbook of Problem-Based Learning", Wiley, 2019 Publication	<1 %
28	Submitted to Brunel University Student Paper	<1 %
29	Submitted to Bogazici University Student Paper	<1 %
30	Hong-Ying Li, Tzu-Chuan Hsu, Chu-Yu Huang, Chien-Lin Kuo, Su-Fen Cheng. "The effectiveness of World Café-based flipped classroom to optimal interprofessional education among interprofessional healthcare workers: A quasi-experimental study", Research Square Platform LLC, 2023 Publication	<1 %
31	journal-center.litpam.com Internet Source	<1 %
32	ejer.com.tr Internet Source	<1 %
33	www.pegegog.net Internet Source	<1 %
34	"STEAM Education", Springer Science and Business Media LLC, 2019 Publication	<1 %
35	Aminah Launuru, Dominggus Rumahlatu, Muhammad Nur Matdoan. "PjBL-HOTS	<1 %

learning model: Its application and effect on cognitive learning outcomes, critical thinking, and social attitudes", BIOEDUPAT: Pattimura Journal of Biology and Learning, 2021
Publication

36 journal.uinsgd.ac.id
Internet Source
<1%

37 journal.unesa.ac.id
Internet Source
<1%

38 proceedings.upi.edu
Internet Source
<1%

39 uppi.uhamka.ac.id
Internet Source
<1%

40 Astuti Astuti, Zulfah Zulfah, Nur Fitriana. "Development of Student Worksheets by Using the Context of Riau Traditional Houses on Quadrilaterals and Triangles", AL-ISHLAH: Jurnal Pendidikan, 2022
Publication
<1%

41 Fikret Korur, Gülfem Efe, Fisun Erdogan, Berna Tunç. "Effects of Toy Crane Design-Based Learning on Simple Machines", International Journal of Science and Mathematics Education, 2015
Publication
<1%

42 Nurulwahida Azid, Ruzlan Md. Ali, Ihsana El Khuluqo, Sigid Edy Purwanto, Eka Nana
<1%

Susanti. "Higher order thinking skills, school-based assessment and students' mathematics achievement: Understanding teachers' thoughts", International Journal of Evaluation and Research in Education (IJERE), 2022
Publication

---

43 Ram Raja Thakuri. "Fostering Engaged Pedagogical Innovation for Meaningful Learning: A Literature Review", Pragyaratna प्रज्ञारत्न, 2023 <1 %
Publication

---

44 Tuba Altiparmak. "The Effects of SCAMPER Technique Activities in the 8th Grade Simple Machines Unit on Students' Academic Achievement, Motivation and Attitude towards Science Lessons", International Journal of Educational Methodology, 2021 <1 %
Publication

---

45 ejournal.undiksha.ac.id <1 %
Internet Source

---

46 scholar.uwindsor.ca <1 %
Internet Source

---

47 ummaspul.e-journal.id <1 %
Internet Source

---

48 www.rsisinternational.org <1 %
Internet Source

49	Dafid Slamet. "The Application of Mathematics Learning Model to Stimulate Mathematical Critical Thinking Skills of Senior High School Students", European Journal of Educational Research, 2021 Publication	<1 %
50	Hutkemri Zulnaidi, Nofouz Mafarja, Suzieleez Syrene Abdul Rahim, Umi Kalsum Mohd Salleh. "Ethical mediation: The influence of mathematics teachers cooperation on readiness for the industrial revolution era in Indonesia and Malaysia", Acta Psychologica, 2024 Publication	<1 %
51	Kuo-Hung Tseng, Chi-Cheng Chang, Shi-Jer Lou, Wen-Ping Chen. "Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment", International Journal of Technology and Design Education, 2011 Publication	<1 %
52	Thi Ngoc Anh Tran, Truong Nguyen Ngoc. "Mobile E-Portfolios on Google Sites: A Tool for Enhancing Project-Based Learning", International Journal of Interactive Mobile Technologies (iJIM), 2023 Publication	<1 %

53	csuepress.columbusstate.edu Internet Source	<1 %
54	discovery.researcher.life Internet Source	<1 %
55	ijhess.com Internet Source	<1 %
56	journal.foundae.com Internet Source	<1 %
57	jptam.org Internet Source	<1 %
58	lib.unnes.ac.id Internet Source	<1 %
59	link.springer.com Internet Source	<1 %
60	malque.pub Internet Source	<1 %
61	ojs.bilpubgroup.com Internet Source	<1 %
62	pp-msu.com.ua Internet Source	<1 %
63	revistas.unilasalle.edu.br Internet Source	<1 %
64	simakip.uhamka.ac.id Internet Source	<1 %

65	stem-in-ed2018.com.au Internet Source	<1 %
66	www.cell.com Internet Source	<1 %
67	www.grafiati.com Internet Source	<1 %
68	www.igi-global.com Internet Source	<1 %
69	www.jppipa.unram.ac.id Internet Source	<1 %
70	www.openaccessojs.com Internet Source	<1 %
71	Adenike Julianah Oladipo, Jeremiah Nosakhare Akhigbe. "Design and implementation of the performance arts enhanced three-stage instructional model", The Journal of Educational Research, 2022 Publication	<1 %
72	digilib.unimed.ac.id Internet Source	<1 %
73	Atina Rahmah Ichtiari, Dahlia Fisher, Taufik Rahman, Siti Ainor Mohd Yatim. "Enhancement of students’ mathematical connection through Knisley mathematics learning model assisted by GeoGebra", Jurnal Elemen, 2024	<1 %

Publication

74	Kate Thompson, Susan Narelle Chapman, Harry Kanasa. "chapter 2 Tools to Mediate Learning and Self-Assessment in a STEAM Unit of Work", IGI Global, 2020 Publication	<1%
75	Shih-Yun Lu, Chih-Cheng Lo, Jia-Yu Syu. "Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp", International Journal of Technology and Design Education, 2021 Publication	<1%
76	Tasos Barkatsas, Nicky Carr, Grant Cooper. "STEM Education: An Emerging Field of Inquiry", Brill, 2019 Publication	<1%
77	repository.upi.edu Internet Source	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		