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Fostering Creative Thinking in Early Learners through STEAM-Based Ecoprint Projects

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Abstract

This research investigates the impact of integrating STEAM (Science, Technology, Engineering, Arts, and Mathematics) project-based learning (PjBL) with Ecoprint activities on developing creative thinking skills in early childhood. A mixed-methods concurrent embedded design was adopted, focusing on preschool children aged 4-6 years from two educational institutions in Karangsari Village, Cirebon District. The study engaged 30 participants in Ecoprint activities, utilizing natural materials to create prints on paper and fabric. The activities were framed within the STEAM PjBL methodology, encompassing stages of Reflection, Research, Discovery, Application, and Communication to facilitate a comprehensive earning experience. Qualitative data, collected through interviews with educators and observations of the Ecoprint projects, were complemented by quantitative assessments of the children's development of creative thinking skills. This dual approach allowed for a rich, multifaceted analysis of the learning processes and outcomes. The creative thinking abilities of the participa were evaluated using a standardized rating scale aligned with criteria set forth by the Ministry of Education and Culture, tracking progress from initial baselines to post-intervention stages. The findings indicate a notable enhancement in creative thinking among the children, with a significant majority advancing from lower levels of creative dev. Children can select and sort the base color materials from the collected leaves. At this stage, the potential of STEAM PjBL, combined with hands-on, environmentally focused artistic activities like Ecoprint, is to enrich early childhood education by fostering creative, innovative thinking. The study's implications extend to curriculum development, advocating for including interdisciplinary, experiential learning strategies that blend scientific inquiry with artistic creativity. However, the research is lim by its scope and its participants' demographic and geographic characteristics. Future studies are recommended to explore the scalability of this a roach and its long-term impacts across diverse educational settings, potentially offering valuable insights into the role of integrated STEAM education in nurturing holistic cognitive development in young learners.

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Introduction

In the 21st century, the dynamic interplay between rapid technological advancements and evolving educational paradigms necessitates a transformative pedagogy approach, especially in early childhood education's foundational years. The global educational agenda increasingly emphasizes the importance of equipping young learners with a suite of competencies known as the 4Cs: creativity, critical thinking, communication, and collaboration (Septikasari, 2018). These competenc are essential for navigating the complexities of the digital age and the future workforce. The integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) within ed tional frameworks has been advocated as a robust strategy to foster these 21st-century skills from an early age, highlighting the need for innovative and interdisciplinary learning models (Aguayo et al., 2023; Haugas, 2023).

Extensive research has underscored the efficacy of the STEAM approach in cultivating an integrated skill set that marries the analytical rigor of STEM disciplines with the creative and flexible thinking fostered by the arts (Areljung, 2022; Chung et al., 2020). This interdisciplinary method not only aligns with the cognitive development trajectories of young learners but also

reflects the collaborative and multifaceted nature of contemporary professional environments (Chaldi & Mantzanidou, 2021; Su, 2024). Moreover, the application of Project-Based Learning (PjBL) within the STEAM framework has been identified as a particularly effective pedagogical strategy, engaging students in active and contextualized learning processes that promote both individual and collaborative problem-solving and innovation (Cohrssen, 2021; Errina et al., 2022).

Despite the growing body of evidence supporting the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) in early childhood education (ECE) for fostering critical and creative thinking skills, significant challenges persist in curriculum development, educator preparedness, and the scalability of such programs. The pedagogical shift towards a STEAM-focused curriculum in ECE necessitates a reevaluation of existing educational materials and teaching strategies to ensure they are conducive to interdisciplinary learning and inquiry-based pedagogy (DeJarnette, 2018; Widiastuti & Yuliati, 2023). Moreover, the successful implementation of STEAM in ECE settings hinges on the professional development of educators, who must be equipped with not only the content knowledge across multiple disciplines but also the pedagogical expertise to facilitate integrated and exploratory learning experiences (Fitriyah & Ramadani, 2021; Mahardika & Putra, 2023). Additionally, the development of age-appropriate STEAM materials that captivate young learners' interests while challenging their cognitive and creative abilities is critical for the effective engagement of children in STEAM learning (Aktürk & Demircan, 2017; Annisa et al., 2019).

The literature further elucidates the necessity of designing STEAM-PjBL (Project-Based Learning) educational and engaging activities for young learners. This dual focus is paramount in early childhood settings, where the intrinsic motivation to learn is closely tied to the enjoyment and relevance of the activities (Errina et al., 2022; Rosita & Rizka, 2023). The incorporation of creative arts through methods such as Ecoprinting presents a novel avenue to achieve this, blending artistic expression with scientific inquiry in a manner that is accessible and appealing to young children (Fatmala & Hartati, 2020; Octariza & Mutmainah, 2021). However, the success of such integrative STEAM activities relies heavily on a nuanced understanding of child development and learning theories, ensuring that these activities are aligned with children's developmental stages and learning styles.

Notwithstanding the promising potential of STEAM-PjBL approaches in cultivating creative and critical thinking from an early age, the research landscape reveals a paucity of empirical studies focused specifically on the impact of these methodologies on creative thinking skills within ECE. While anecdotal and qualitative evidence points to the efficacy of STEAM-PjBL in enhancing engagement and learning outcomes, there remains a gap in quantitative research that rigorously evaluates the cognitive and developmental impacts of these approaches on young learners (DeJarnette, 2018; Widiastuti & Yuliati, 2023). This gap underscores the need for methodologically robust studies that can provide concrete evidence of the benefits of STEAM-PjBL, thereby informing curriculum development, teacher training programs, and educational policy decisions aimed at optimizing early childhood education for the demands of the 21st century.

In identifying the limitations and controversies within the existing body of research, this study acknowledges the need for a deeper understanding of how STEAM-PjBL activities can be optimized for early childhood education. The challenge lies in balancing the inherent complexity of STEAM subjects with the developmental needs and interests of young children, ensuring that these educational experiences are effective and enjoyable. This research aims to contribute to early childhood education by offering a detailed exploration of STEAM-PjBL through Ecoprinting activities. This study seeks to provide actionable insights for educators and policymakers on integrating STEAM principles into early learning environments by focusing on developing creative thinking skills. The ultimate goal is to enrich the educational experiences of young learners, equipping them with the critical and creative thinking skills necessary for success in the 21st century.

Methods

This study employed a mixed-methods approach with a concurrent embedded design to explore the impact of STEAM Project-Based Learning (STEAM-PjBL) through Ecoprint projects on developing creative thinking skills in early childhood education. The research combined qualitative data, primarily descriptions of the STEAM-PjBL learning processes in preschool settings, with quantitative data on the progression of children's creative thinking abilities involved in the study (Cresswell, 2017; Sugiyono, 2016).

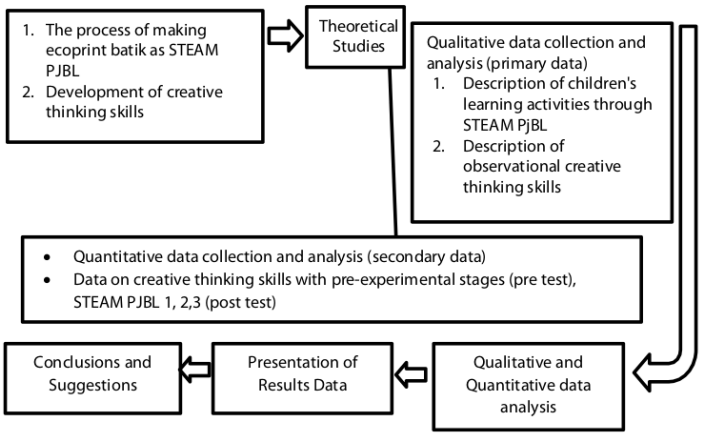

Figure 1. Research Activity Flow with Concurrent Embedded Mixed Method

The qualitative data were collected through interviews with teachers and observations during the project activities at two preschools in Karangsari Village, Cirebon District, namely RA Al-Hikmah and RA Miftahul Ulum. At RA Al-Hikmah, the implementation was conducted in Class A (ages 4-5), and at RA Miftahul Ulum, it was in the B group (ages 5-6). The subjects included 30 children aged 4-6 years from these schools, engaged in three distinct Ecoprint activities: (1) Ecoprint on Paper, (2) Ecoprint on Fabric using the pounding technique, and (3) Ecoprint on Fabric using the steaming technique.

Qualitative data gathering involved interviews, direct observations, and documentation of the STEAM-PjBL project implementation. The quantitative data were derived from observational assessments of the children's development of creative thinking skills. Data reduction was performed on interview responses, presented narratively, while observational data on teacher and student activities were described descriptively for each STEAM-PjBL session. The progression of each child's creative thinking ability was evaluated against specific criteria using a rating scale based on the Ministry of Education and Culture (Hasbi et al., 2020), Not Yet Developed (BB), Beginning to Develop (MB), Developing as Expected (BSH) and Very Well Developed (BSB). Observation data on the development of children who participated in the project were categorized on a scale of 1-4.

The data's recapitulation is then analyzed descriptively statistically by calculating the percentage of the number of children who enter specific criteria using the following formula.

$$P = \frac{f}{n} \times 100\%$$

Information:

p = percentage of children with specific developmental criteria

f = frequency/number of children who fit into a specific developmental criterion

n = total number of children

The percentage results are categorized with reference in the following table:

Table 1. Interpretation of Data Processing Results

Percentage (%)	Kategori
76-100	Very High
51-75	High
26-50	Low
0-25	Very Low

Result

This section discusses the development results in physical models, procedural models, and individual expert evaluations consisting of learning materials experts, learning design experts, and teachers.

his research yielded both qualitative and quantitative data. Qualitative data were obtained regarding the implementation of STEAM-PjBL using Ecoprinting, while quantitative data pertained to observations of the development of creative thinking skills.

3.1. Implementation of STEAM Project-Based Learning through Ecoprint Play

The Ecoprint project followed the STEAM PjBL stages from Reflection, Research, Discovery, and Application to Communication. The Ecoprint Project involved batik activities using natural materials like leaves and flowers for patterns. The ecoprint activity was carried out in three sessions: Ecoprint on Paper using the pounding technique, the ecoprint on fabric with the pounding technique, and the ecoprint on fabric using the steam technique. Observations were made, and descriptive data about the activity's execution were collected. Each activity was conducted following the STEAM PjBL stages.

Figure 2. First Ecoprint Activity on Paper with Pounding Technique

The first trial of ecoprint, as shown in Figure 2, used paper as the medium, where the children initially randomly selected leaves. The children were not yet proficient in creating leaf patterns since it was their first attempt. The outcomes varied, reflecting each child's creative ideas. During the Reflection process, the children applied their prior knowledge that many leaves are green. They collected eco-print materials from various leaf and flower shapes. In the reflection stage, the teacher acted as a facilitator, assisting the children with stimulating questions relevant to the project.

Figure 3. Teachers as facilitators when posing stimulating questions

Teachers play a role as facilitators in the ecoprint project conducted by children. As depicted in Figure 3, teachers can pose stimulating questions, such as inquiring about the types of leaves collected. Other questions to elicit children's knowledge can also be introduced at this stage.

During the Research phase, children observe and identify the leaf print outcomes, including the various colors produced. They experiment with different leaves gathered, pressing them onto paper, noting the printed shapes, the sharpness of the colors produced, and whether the colors that appear match the original leaf colors before pressing. Children identify beautifully shaped leaf prints and observe the perfection of the colors transferred onto the paper. According to interviews with teachers at RA Al-Hikmah, it was mentioned that one child began to record the names of leaves that printed in colors different from their natural hues. In contrast, at RA Miftahul Ulum, two children asked their teacher: "Can the color of this wild leaf be used on clothes?".

In the Discovery phase, children learn that not all green leaves produce the same color, and the same applies to flowers. They discover, for example, that guava leaves turn brown when pressed onto paper and teak leaves turn purple, even though both are originally green. Similarly, they find that the yellow cosmos flowers turn orange upon pressing, the pink periwinkle flowers turn purple, and the white ones turn brown when pressed.

Figure 4. Ecoprint Activities on Fabric Using Pounding Technique

In the batik-making activity using fabric, children can discover that the colors emerging on the fabric do not always match the colors of the leaves, as illustrated in Figure 4. Children pound natural materials, in this case, leaves, using a wooden hammer and find that these leaves can produce varying colors on the fabric.

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Children move on to the Application phase following the Reflection, Research, and Discovery stages. Here, they start their eco-print project on fabric materials, still employing the same technique. Children apply leaves and flowers as desired to achieve the product design they envision.

Figure 5. Application Stage of Ecoprint Project Design

After a series of experiments with different media, their creative thinking skills begin to be observed as children enter the application stage. As shown in Figure 5, each child starts to design their project differently from one another. Children can select and sort through the base color materials from the collected leaves at this stage.

In the final stage, the teacher gives the children the opportunity to explain the projects they have created. They discuss the steps they have taken and the results they have achieved. Children reveal that wild plants offer natural colors suitable for eco-print batik. This stage serves as the Communication phase in the STEAM PjBL ecoprint project.

3.2. Enhancing Creative Thinking Skills through STEAM Project-Based Learning (PjBL) via Ecoprinting

This study also yielded data on assessing the development of creative thinking, which was observed through an observation checklist before and during the project implementation. The observational data for creative thinking skills prior to project implementation can be seen in the following table:

Table 2. Observation Results of AUD (Early Childhood) Creative Thinking Skills

No	Child's Initials	Pra	STEM PjBL-1	STEAM PjBL-2	STEAM PjBL-3
1	AF	MB	MB	BSH	BSH
2	AI	MB	MB	BSH	BSH
3	AAG	BB	BB	MB	BSH
4	DK	MB	MB	MB	BSH
5	ENZ	BB	MB	MB	MB
6	FR	BB	MB	BSH	BSH
7	HAQ	BB	BB	MB	BSH
8	MAN	BB	MB	BSH	BSH
9	MAA	BB	BB	MB	MB
10	N	BB	MB	MB	BSH
11	NF	BB	MB	MB	BSH
12	SZ	BB	MB	MB	BSH
13	S	BB	BB	MB	MB

14	SA	BB	BB	MB	BSH
15	V	BB	BB	MB	BSH
16	WD	BB	BB	MB	MB
17	RN	BB	MB	MB	BSH
18	R	BB	BB	BB	MB
19	AD	BB	BB	BSH	BSH
20	KA	BB	MB	MB	BSH
21	MA	MB	MB	MB	BSH
22	A	MB	MB	BSH	BSH
23	AA	MB	MB	MB	BSH
24	BAK	MB	MB	MB	BSH
25	D	MB	MB	BSH	BSB
26	FA	MB	MB	BSH	BSB
27	HS	MB	MB	BSH	BSH
28	K	MB	MB	BSH	BSB
29	MI	BB	MB	MB	BSH
30	HF	MB	MB	BSH	BSH

The data in Table 2 delineates the observational outcomes of creative thinking skills in early childhood participants before and throughout implementing a STEAM (Science, Technology, Engineering, Arts, and Mathematics) Project-Based Learning (PjBL) project integrated with Ecoprint activities. The assessment of the children's creative thinking skills was grounded on a rating scale developed by the Ministry of Education and Culture, encompassing four levels: Not Yet Developed (BB), Beginning to Develop (MB), Developing as Expected (BSH), and Very Well Developed (BSB).

The data analysis reveals a noticeable enhancement in the children's creative thinking skills from the baseline (Pre) to each subsequent STEAM PjBL session. The majority of the children exhibited progress from the "Not Yet Developed" or "Beginning to Develop" stages to the "Developing as Expected" or "Very Well Developed" stages. This progression signifies that integrating STEAM PjBL with Ecoprint activities potentially fosters the development of creative thinking skills in early childhood.

3.3. Achievement in Children's Creative Thinking Skills

The observation results of early childhood creative thinking skills before and during the project can illustrate the contribution of STEAM-PjBL to the increase in the development of creative thinking skills, as shown in the following diagram:

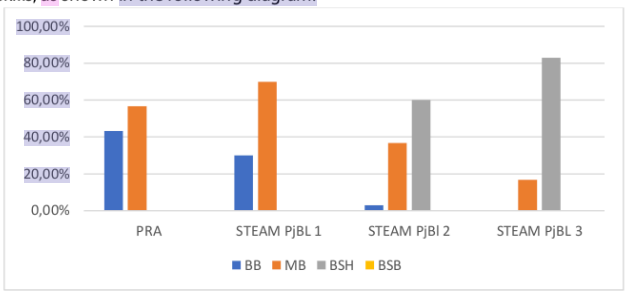

Figure 6. Diagram of the progress in enhancing creative thinking skills

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Figure 6 shows that, before project implementation, the children's creative thinking skills were at the Not Yet Developed (BB) and Beginning to Develop (MB) levels. Subsequently, there was a significant increase during the first project, and by the second project, 60% of the children had started to reach the Developing as Expected (BSH) category. In the final project, this increased to 83% of children at the Developing as Expected (BSH) level, a percentage that, when reverted to categorization, indicates a very high contribution.

In conclusion, the data affirm that STEAM-PjBL significantly develops early childhood creative thinking abilities. The progression from undeveloped and beginning to develop stages to a high percentage at the Developing as Expected level demonstrates the effectiveness of this interdisciplinary and project-based learning approach in stimulating and supporting the growth of children's creativity. It underscores the importance of an interdisciplinary and project-based approach in early childhood education for developing essential critical and creative skills crucial for their growth and learning.

Discussion

In exploring STEAM project-based learning (PjBL) through Ecoprint activities, this study illuminates the intricate interplay between educational methodologies and early childhood creative thinking. Incorporating natural elements in Ecoprint projects aligns with the environmental ethos of contemporary educational practices, emphasizing sustainability and hands-on learning (Kusumaningtyas & Wahyuningsih, 2021; Octariza & Mutmainah, 2021). This approach fosters an appreciation for the natural world and cultivates a deeper understanding of ecological principles from a young age (Duo-Terron et al., 2022; Zhao & Guo, 2019).

The findings of this study reveal a significant enhancement in children's creative thinking skills, evidenced by the progression from initial stages of creative skill development to more advanced levels through repeated Ecoprint projects. This progression underscores the efficacy of STEAM PjBL in nurturing creativity, supporting the hypothesis that experiential learning through project-based activities can effectively augment cognitive skills in early childhood (Azizah et al., 2022; Yildiz & Guler Yildiz, 2021). Moreover, as noted in previous studies, the collaborative aspect of these projects plays a crucial role in enhancing creative thinking, highlighting the synergistic effect of cooperative learning environments (Rianti et al., 2022; Segundo-Marcos et al., 2023).

Comparative analysis with existing literature suggests a consonance with the findings of similar STEAM-based interventions, where hands-on, project-based learning methodologies have been shown to significantly impact cognitive and creative skill development in children (Arpaci et al., 2023; Başaran & Bay, 2023). However, this study's unique contribution lies in integrating the Ecoprint technique, providing a novel context for applying STEAM principles. This integration reinforces the versatility of STEAM education and extends its applicability to environmental and artistic domains, enriching the pedagogical landscape (Land, 2013; Xue, 2022).

The study highlights that STEAM PjBL, through the complex Ecoprint activities, effectively merges scientific exploration with artistic expression to enhance children's creative thinking. These activities, involving hands-on interaction with natural elements to create art, promote critical thinking and problem-solving and drive innovation and originality, vital for creative thought (Albar & Southcott, 2021; Juškevičienė et al., 2021; Weng et al., 2022). The observed post-intervention improvements affirm STEAM PjBL's role in nurturing vital 21st-century skills. Nonetheless, the findings' broader applicability may be limited by the study's specific Ecoprint context and design, suggesting the need for further research to assess these pedagogical approaches' long-term effects on children's creativity and cognitive growth (Hu et al., 2023; Weckström et al., 2022).

The observed enhancement in creative thinking skills through STEAM PjBL via Ecoprinting underscores the importance of innovative educational practices in early childhood development. These findings echo the sentiments of broader educational research, advocating for incorporating art and environmental stewardship into the STEM curriculum to foster a holistic educational experience (Khotimah et al., 2023; Suharsono et al., 2022). The significance of these results lies not only in their contribution to the academic discourse on STEAM education but also in their practical implications for curriculum development, emphasizing the need for creative and environmentally conscious educational strategies (Nopiyanti et al., 2020; Parker et al., 2022).

While the results of this study are promising, caution must be exercised in their interpretation due to the specific context and methodology employed. The unique setting of Ecoprint projects and the specific demographic of participants may limit the generalizability of the findings. Further research is needed to explore the scalability of such interventions across diverse educational settings and to examine the long-term impact of STEAM PjBL on creative thinking skills (Weckström et al., 2022; Hu et al., 2023).

In conclusion, this study highlights the potential of integrating STEAM PjBL with Ecoprint activities to enhance early childhood creative thinking skills. The implications of these findings extend beyond the immediate educational context, suggesting avenues for future research and curriculum development. The integration of environmental education and creative arts within the STEAM framework not only enriches the learning experience but also prepares children to navigate and contribute to a rapidly evolving world with creativity, critical thinking, and ecological awareness (Jaruchainiwat et al., 2024; Zayyinah et al., 2022).

Conclusion

This study meticulously examined the application of STEAM project-based learning (PjBL) through Ecoprint activities, aiming to enhance creative thinking skills in early childhood. By integrating hands-on engagement with natural materials and following the STEAM PjBL stages Reflection, Research, Discovery, Application, and Communication—children demonstrated significant advancements in creative thinking, transitioning from initial stages of development to achieving "Developing as Expected" levels in a substantial majority by the project's end. The research findings indicate a significant progression in the creative thinking skills of the children, who moved from initial levels of "Not Yet Developed" or "Beginning to Develop" to predominantly "Developing as Expected" by the conclusion of the project. This transformation underscores the effectiveness of STEAM PjBL in nurturing creativity through experiential learning and environmental engagement. The study's outcomes suggest that such an integrative educational approach can have profound implications for early childhood education, potentially leading to developing a holistic curriculum that fosters innovative thinking and ecological consciousness from a young age. Despite its promising outcomes, the study acknowledges limitations such as its restricted educational setting and participant range. It recommends future research to explore the scalability and long-term impacts of such pedagogical approaches across diverse contexts. This exploration could further substantiate the role of environmental education and creative arts within STEAM education, enriching learning experiences and preparing children to contribute creatively and responsibly to their world.

Declarations

Author contribution statement

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