Vol. 4, No. 4, December 2026, pp. 3793-3802
INTERNATIONAL JOURNAL OF
POST AXIAL
FUTURISTIC TEACHING AND LEARNING
https://journal.amorfati.id/index.php/postaxial | | ISSN 3025-7549

The Implementation of STEAM-Based Learning on Creative Thinking Skills and Developmental Outcomes in Early Childhood

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Article History:
Received:
14-09-2026
Revised:
22-10-2026
Accepted:
12-11-2026
Avaiable online:
06-12-2026

Keywords:
STEAM, Early childhood, Creative thinking, Cognitive development

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Abstract:
Creative thinking and cognitive abilities need to be developed through active learning that provides children with hands-on experiences. This study aimed to determine the effect of STEAM-based learning through mung bean growth activities on the creative thinking and cognitive abilities of early childhood students. The study employed a quantitative approach using a posttest-only control group design involving 21 children divided into experimental and control groups. Data were collected using observation sheets and analyzed using an independent-samples t-test. The results revealed statistically significant differences between the experimental and control groups across all four creative thinking indicators: fluency ($t(19) = -3.228$, $p = 0.004$), flexibility ($p < 0.001$), originality ($t(19) = -3.246$, $p = 0.004$), and elaboration ($t(19) = -6.309$, $p < 0.001$). Cognitive abilities also showed a statistically significant difference between the two groups ($t(19) = -8.79$, $p < 0.001$). These findings indicate that STEAM-based learning through mung bean growth activities can provide meaningful opportunities for children to explore, generate ideas, observe changes, and solve simple problems. Practically, this approach offers teachers an alternative learning strategy that integrates scientific exploration, creative expression, and cognitive stimulation through simple, contextual, and hands-on activities. Thus, STEAM-based learning through mung bean growth activities has the potential to support the development of creative thinking and cognitive abilities in early childhood.

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Introduction (مقدمة)

Early childhood education (PAUD) is a stage of education that plays a crucial role as the foundation for children's development in subsequent stages (Alfadhilah, 2025). During this period, children undergo rapid development, so the learning experiences provided must be tailored to their characteristics, needs, and developmental stages. According to Kasmiati (2025), early childhood education is not only focused on mastering academic skills but also on supporting children's holistic development, encompassing cognitive, language, social-emotional, physical-motor, and creative aspects. Therefore, the early childhood learning process should provide children with opportunities to learn through real-world experiences, play, observe their environment, try new things, and explore their surroundings (Gea and Zega, 2025). These learning experiences can serve as a foundation for children to develop their thinking skills, solve simple problems, generate various ideas, and foster creativity in line with their imagination (Bali et al., 2025).

In practice, learning activities in early childhood education (PAUD) still tend to focus more on guiding children to follow examples provided by teachers (Anhar, 2026). This type of activity pattern can limit children's opportunities to experiment, develop ideas, and produce work based on their own concepts. Ratnawati et al. (2025) indicate that providing examples of work that children must imitate can hinder their originality and freedom of expression, whereas Mariana and Yuliantina (2023) explain that exploratory activities provide children with opportunities to develop ideas and solve problems more independently. Similar conditions were found in a preliminary study at SPS Nusa Indah 63, where some children still tended to be passive in participating in activities, waiting for the teacher's instructions before carrying out tasks, and had not yet demonstrated initiative in developing ideas or creating something in their own way. These conditions indicate the need for learning strategies that encourage children to actively explore, experiment, and develop their own ideas rather than merely imitate the examples provided by teachers.

Creative ability in early childhood can be observed through a child's ability to generate and develop ideas in various types of activities (Sholihah et al., 2025). In measuring children's creativity, four observable aspects can be identified: fluency, which relates to the number of ideas generated; flexibility, which indicates the diversity of ideas; originality, which relates to the emergence of unique ideas; and elaboration, which is evident in a child's ability to add details to an idea or a piece of work. These aspects are reflected in research on early childhood creativity using the Torrance Test of Creative Thinking (TTCT), which has been applied to children aged 5–7 years. The four aspects are interconnected and can be stimulated through learning activities that provide opportunities for children to generate multiple ideas, explore different possibilities, express original thoughts, and develop their ideas into more detailed forms. In line with this, Garaigordobil and Berrueco (2011) demonstrated that activities that provide children with opportunities to play and explore can support the development of creative thinking, including fluency, flexibility, originality, and elaboration, in preschool-aged children.

STEAM-based learning is an approach that integrates Science, Technology, Engineering, Arts, and Mathematics into learning activities that are closely tied to children's experiences (Niri et al., 2026). The integration of these five disciplines provides a learning framework that encourages children to observe phenomena (Science), use tools and materials (Technology), design and construct objects (Engineering), express ideas creatively (Arts), and recognize patterns or quantities (Mathematics). In early childhood education, STEAM can therefore be implemented

through activities that provide children with opportunities to observe, experiment, explore, design, create, calculate, and solve simple problems. Wahyuningsih et al. (2020) explain that STEAM learning in early childhood can be carried out through observation of the environment and integrated activities, thereby making children more active and giving them the opportunity to construct their own knowledge. In line with this, the results of a systematic review indicate that STEAM learning in early childhood emphasizes exploration, hands-on experiences, creativity, and problem-solving as part of the child's learning process (Afrilliany et al., 2026). The integration of these learning experiences is theoretically relevant to creative thinking development because children are encouraged to generate ideas, consider different approaches, produce original creations, and elaborate on their work. At the same time, observing, comparing, identifying changes, and solving simple problems provide opportunities to stimulate children's cognitive abilities.

Previous studies have demonstrated the potential of STEAM-based learning in supporting early childhood development. Pitaloka and Sinaga (2022) found that STEAM-based learning influences the creative thinking skills of early childhood students, while Tajqiyah et al. (2024) demonstrated that the implementation of STEAM using loose parts can enhance children's cognitive abilities. Another study by Maharani and Dewi (2025) also showed an improvement in the creative thinking skills of 5–6-year-old children through STEAM learning. These findings provide evidence that STEAM can support both creative thinking and cognitive development. However, previous studies have generally examined STEAM through different learning activities and learning media, such as loose parts, without specifically focusing on mung bean growth activities as an integrated learning experience. Furthermore, the simultaneous examination of creative thinking and cognitive abilities through a single contextual STEAM activity remains an important area to investigate. Therefore, further research is needed to explore how STEAM-based learning through concrete and familiar activities can stimulate both aspects of children's development.

In this study, STEAM learning was implemented through a mung bean growth activity that is relevant to children's daily lives and can be carried out using simple tools and materials. This activity integrates Science through planting, observing, and identifying the stages of mung bean growth; Technology through the use of simple tools and materials; Engineering through preparing planting media and arranging the growing environment; Arts through creative expression in designing and decorating the planting containers; and Mathematics through counting seeds, observing growth, and comparing plant sizes. The activities of planting, caring for, and observing changes in the plants provide children with hands-on experiences to explore their environment while engaging their thinking skills. The novelty of this study lies in the use of mung bean growth activities as a contextual STEAM-based learning strategy that integrates all five STEAM components into a series of practical learning experiences and examines their effects on two developmental outcomes simultaneously, namely creative thinking and cognitive abilities. Unlike previous studies that focused on particular STEAM activities or developmental outcomes, this study combines plant growth exploration with the stimulation of both creative thinking and cognitive development in one learning context. This study was conducted at SPS Nusa Indah 63, Kebonsari, Sabrang, Ambulu Subdistrict, Jember Regency, with the mung bean growing activity as the primary learning activity. Accordingly, this study aimed to determine the effect of STEAM-based learning through mung bean growth activities on the creative thinking and cognitive abilities of early childhood students.

Method (منهج)

This study is a quantitative study using a posttest-only control group design, conducted at one of the SPS Nusa Indah 63 schools during the odd semester of the 2025/2026 academic year. An illustration of the research design can be seen in Figure 1.

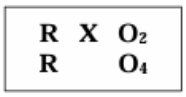

Figure 1: Posttest-Only Control Group Design (Sugiono, 2016)

Description:

R : Two randomly selected groups
X : Treatment
O_2 : Posttest for the experimental class
O_4 : Control group posttest

The population in this study consisted of all children participating in learning activities at SPS Nusa Indah 63, Kebonsari, Sabrang, Ambulu Subdistrict, Jember Regency. The research sample consisted of two groups of children already enrolled at the institution: the experimental group and the control group. Sampling was conducted using purposive sampling, taking into account the suitability of group characteristics, the children's ages, classroom conditions, and considerations from the institution. The number of research samples is presented in Table 1 as follows:

Table 1. Number of Groups

Group	Number of Children
Experiment	10
Control	11
Total	21

The research was conducted over three learning sessions. The experimental group participated in STEAM-based learning through mung bean-growing activities, while the control group followed the learning activities commonly implemented by teachers. Data were collected using observation sheets to assess children's creative thinking and cognitive abilities. Creative thinking was measured through four indicators: fluency, flexibility, originality, and elaboration. Meanwhile, cognitive abilities were assessed through six indicators: observing changes, grouping and identifying objects, counting, comparing, understanding cause-and-effect relationships, and solving simple problems. Both instruments used a four-point rating scale ranging from 1 to 4. The selection of 21 participants was based on the availability of two existing groups at the research site, consisting of 10 children in the experimental group and 11 children in the control group. These participants represented all children in the two groups who were included in the study.

The experimental class received STEAM-based instruction through a mung bean-growing activity, while the control class received instruction using activities typically employed by teachers without the application of STEAM. After the learning activities were completed, both groups were observed again to assess the children's creative thinking and cognitive abilities.

Data analysis began with a normality test. If the data are normally distributed, an independent samples t-test is used. The test is conducted using SPSS software at a significance level of 0.05; if the data are not normally distributed, the Mann–Whitney test is used, also at a significance level of 0.05. A difference is considered significant if the p-value is less than 0.05 (Sugiono, 2022).

Result (نتائج)

The research results indicate changes in the children's abilities after participating in STEAM-based learning activities. These changes were evident in the children's creative thinking and cognitive abilities during the mung bean growth activity. The results of the normality test for creative thinking abilities are presented in Table 2, and those for cognitive development are presented in Table 3.

Table 2. Normalization Test for Creative Thinking Ability

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Hasil	Kelas kontrol	.231	11	.104	.876	11	.093
	Kelas eksperimen	.149	10	.200*	.918	10	.341

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results of the Shapiro-Wilk normality test showed a p-value of 0.093 for the control group and 0.341 for the experimental group. Since both values are greater than 0.05, the data for the control and experimental groups are normally distributed.

Table 3. Cognitive Development Test Results

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
Hasil	1	.159	10	.200*	.933	10	.482
	2	.153	11	.200*	.958	11	.741

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results of the Shapiro-Wilk normality test showed a p-value of 0.482 for the control group and 0.741 for the experimental group. Since both values are greater than 0.05, the data for both groups are normally distributed.

Based on the results of the normality test, all research data follow a normal distribution. Therefore, the analysis continued with a t-test to statistically determine the differences or effects under investigation, as follows:.

a. Results of the independent-samples t-test for Creative Thinking Ability

Table 4. Liquidity Indicators

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Kelancaran	Equal variances assumed	.415	.527	-3.228	19	.004	-.845	.262	-1.394	-.297
	Equal variances not assumed			-3.188	16.945	.005	-.845	.265	-1.405	-.286

The results of the independent samples t-test indicate a significant difference in fluency between the two groups (t(19) = -3.228; p = 0.004 < 0.05), with a mean difference of -0.845.

Table 5. Flexibility Indicators

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Keluwesan	Equal variances assumed	1.006	.328	-4.680	19	.000	-1.236	.264	-1.789	-.683
	Equal variances not assumed			-4.742	18.507	.000	-1.236	.261	-1.783	-.690

Based on the results of the Independent Samples t-Test, a Sig. (2-tailed) value of 0.000 (< 0.05) was obtained after the assumption of homogeneity of variances was met via Levene's Test (Sig. 0.328 > 0.05). These statistical results empirically indicate that there is a statistically significant difference in flexibility levels between the two sample groups studied.

Table 6. Authenticity Indicators

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Keaslian	Equal variances assumed	.710	.410	-3.246	19	.004	-.864	.266	-1.421	-.307
	Equal variances not assumed			-3.285	18.616	.004	-.864	.263	-1.415	-.313

The results of the independent samples t-test indicate a significant difference in authenticity between the two groups (t(19) = -3.246; p = 0.004 < 0.05), with a mean difference of -0.864.

Table 7. Degradation Indicators

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Penguraian	Equal variances assumed	.510	.484	-6.309	19	.000	-1.600	.254	-2.131	-1.069
	Equal variances not assumed			-6.373	18.807	.000	-1.600	.251	-2.126	-1.074

Based on the independent samples t-test (assuming equal variances), there was a statistically significant difference in the Decomposition variable, with a value of t(19) = -6.309 and p < 0.001.

a. Results of the independent-samples t-test for Cognitive Development

Table 8. t-Test for Cognitive Development

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Hasil	Equal variances assumed	.125	.728	-8.786	19	.000	-6.755	.769	-8.364	-5.145
	Equal variances not assumed			-8.782	18.779	.000	-6.755	.769	-8.366	-5.143

The results of the t-test showed a statistically significant difference, $t(19) = -8.79$, $p < 0.001$, with a 95% confidence interval ranging from -8.36 to -5.15. These results indicate that there is a significant difference between the two groups tested. Thus, the analysis results indicate that the treatment administered produced a significant change in the variable under study.

Discussion (مناقشة)

The difference in creative thinking abilities between the experimental group and the control group indicates that STEAM-based learning provides learning experiences that encourage children to participate more actively in the learning process. In the experimental group, children not only received instructions from the teacher but also participated directly in a series of activities involving planting and observing the growth of mung beans. These activities provided opportunities for children to generate ideas, experiment, make decisions, and create something through hands-on experiences. In contrast, the control group followed conventional learning activities, which provided relatively fewer opportunities for independent exploration. This finding suggests that the learning process, particularly the opportunities provided for children to explore and express their ideas, may contribute to differences in creative thinking abilities. This is consistent with Wahyuningsih et al. (2020), who explained that STEAM learning encourages children to actively construct their own knowledge through integrated learning experiences. Furthermore, Pitaloka and Sinaga (2022) found that STEAM-based learning influences early childhood creative thinking skills. Thus, the present findings reinforce previous research by demonstrating how contextual activities involving plant growth can provide opportunities for children to express and develop their creativity.

In the fluency indicator, children were involved in preparing tools and materials such as plastic cups, cotton, and mung beans. This activity provided opportunities for children to identify the materials needed and express their ideas regarding the preparation of the planting activity. Through direct involvement, children could become more active in recognizing and selecting the materials required to complete a task. These experiences are relevant to the development of fluency because children are encouraged to express ideas and respond to the needs of an activity. However, the development of fluency is not merely demonstrated through identifying materials but also through the ability to generate several relevant ideas. Therefore, opportunities for children to mention different materials or suggest alternative ways of preparing the activity are important aspects of this indicator. This finding is in line with Garaigordobil and Berrueco (2011), who demonstrated that exploratory and play-based activities can support the development of fluency in preschool-aged children.

For the flexibility indicator, children arranged moistened cotton in a cup and then placed mung beans on top of it. This activity allowed children to organize materials directly and respond to the conditions they encountered during the planting process. Through this experience, children had opportunities to explore different ways of arranging materials and adjust their actions according to their observations. Flexibility is reflected in children's ability to use different approaches or consider alternative solutions when completing a task. Therefore, the opportunity

to arrange materials independently is relevant to developing flexible thinking, particularly when children are encouraged to try different arrangements rather than follow only one predetermined procedure. This finding supports the perspective of Mariana and Yuliantina (2023), who emphasized that exploratory activities provide children with opportunities to develop ideas and solve problems more independently. The children's activities are shown in Figures 1 and 2 below.



Figure 1. A Child Preparing Tools and Materials



Figure 2. A Child Arranging Cotton and Green Beans

For the originality indicator, children were given the opportunity to decorate the glasses used in the mung bean planting activity. This activity provided space for children to express their ideas through their choices of shapes, colors, and decorative designs. Since children were not required to produce identical decorations, they could create different products according to their individual ideas and preferences. The differences in their creations reflect opportunities to express original ideas and demonstrate individual creativity. This activity is important because originality develops when children are given freedom to produce something that is not limited to imitating a predetermined example. This finding is consistent with Ratnawati et al. (2025), who indicated that excessive emphasis on imitating examples can limit children's originality and freedom of expression. It also supports the findings of Maharani and Dewi (2025), who reported improvements in the creative thinking skills of children aged 5–6 years through STEAM-based learning.

For the elaboration indicator, children colored pictures of mung bean sprouts. Through this activity, children were encouraged to observe the shapes and parts of the sprouts and express their observations through coloring. This activity provided opportunities for children to pay attention to visual details and develop their representations of the observed objects. Elaboration involves the ability to add details, expand ideas, and develop an initial concept into a more complete form. Therefore, this indicator can be reflected not only through coloring but also through children's ability to add details to their drawings or explain specific characteristics of the mung bean sprouts they observed. The activity connects observation with creative expression, allowing children to develop their understanding of an object through visual representation. This is in line with Garaigordobil and Berrueco (2011), who found that exploratory activities can support the development of elaboration as one of the components of creative thinking. The children's activities are shown in Figures 3 and 4 below.w



Figure 3. Decorating a Glass



Figure 4. Coloring a Picture of a Sprout

Cognitive development through STEAM-based learning provides children with opportunities to acquire knowledge through objects and phenomena that can be observed directly. The mung bean growth activity allows children to recognize tools and materials, observe the growth process, identify changes, compare conditions, and understand simple relationships between the activities they perform and the results they observe. These experiences encourage children to construct their understanding through direct interaction with their environment rather than relying solely on verbal explanations from the teacher. The learning process is relevant to the characteristics of early childhood, in which concrete experiences provide opportunities to develop understanding through observation, exploration, and active participation. This finding is consistent with Wahyuningsih et al. (2020), who emphasized that integrated STEAM activities enable children to construct their own knowledge through environmental exploration. Furthermore, Tajqiyah et al. (2024) demonstrated that STEAM implementation using loose parts can enhance children's cognitive abilities. The present study extends these findings by utilizing mung bean growth activities as a contextual learning experience that connects observation, identification, counting, comparison, cause-and-effect understanding, and simple problem-solving.

Conclusion (خاتمة)

Based on the research findings, it can be concluded that STEAM-based learning through mung bean cultivation activities revealed differences in creative thinking and cognitive abilities between the experimental and control groups. In terms of creative thinking, differences were observed in the indicators of fluency, flexibility, originality, and elaboration, with the experimental group demonstrating better performance. STEAM-based learning provides children with hands-on experiences through activities such as preparing materials, planting, decorating, observing, and creating works, thereby giving them the opportunity to explore, experiment, and develop their ideas. The research results also indicate differences in cognitive abilities between the two groups. Thus, STEAM-based learning through mung bean growth activities can serve as an alternative learning activity to support the creative and cognitive abilities of early childhood students.

Acknowledgment (شكر وتقدير)

The author would like to express gratitude to SPS Nusa Indah 63, Kebonsari, Sabrang, Ambulu Subdistrict, Jember Regency, for granting permission and supporting the conduct of this study. Thanks are also extended to the teachers and children who participated in the research activities, as well as to all parties who provided assistance and support—both directly and indirectly—so that this study could be successfully carried out.

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