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Project-Based Learning Integrated with STEAM: A Study on Educational Pop-Up Books for Early Literacy

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Abstract
This study evaluates the effectiveness of integrating Project-Based Learning (PjBL) with Science, Technology, Engineering, Arts, and Mathematics (STEAM) to enhance literacy skills among children aged 5-6. Employing a quasi-experimental design, 30 TK Cornerstone Homestyle Education students were selected and divided into experimental and control groups. The experimental group engaged in PjBL integrated with STEAM, while the control group followed conventional methods. Pre-tests and post-tests were administered to assess literacy skills, focusing on reading habits, symbol recognition, word writing, and constructing written pieces. Data were collected through tests and observation sheets and analyzed using descriptive and inferential statistics via IBM SPSS Statistics version 21. Results showed significant literacy skill improvements in the experimental group compared to the control group, with higher post-test scores and increased engagement. Instrument validity was confirmed through item analysis, and reliability was ensured with a Cronbach's Alpha of 0.74. Observations revealed high implementation quality in both groups, but the experimental group demonstrated a more substantial increase in literacy levels. This study concludes that STEAM-integrated PjBL effectively enhances early literacy, promotes creativity, and engages students actively in learning. The findings imply the need for broader application of this method in early childhood education and suggest further research to explore long-term impacts and applicability across diverse educational contexts. Despite limitations such as sample scope and short-term intervention, this research supports adopting interdisciplinary approaches for improved educational outcomes.

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Introduction

Literacy is essential in early childhood education, serving as the cornerstone for children's language development and subsequent educational success (Setiyaningsih & Syamsudin, 2018). Early literacy encompasses essential skills such as reading and writing, crucial for a child's adaptation to more advanced educational stages (Fahmi et al., 2020). These foundational literacy skills facilitate academic achievement and contribute to lifelong learning (Ningrum & Abdullah, 2021). Despite its importance, Indonesia faces significant challenges in improving literacy rates among young children, as evidenced by various international and national assessments (Mullis & Martin, 2017; Purnamasari & Asri, 2019). Addressing these challenges is crucial for fostering a literate society capable of critical thinking and innovation. The low literacy rates among Indonesian children, particularly in rural areas, highlight the urgency for effective interventions and educational strategies to bridge these gaps and support early literacy development (Kemdikbud, 2017).

Previous studies have explored various strategies to enhance early childhood literacy. Integrating health education into preschool programs has shown promising results in improving knowledge and attitudes among parents and educators (Guerrero et al., 2023; Yan & Hu, 2023). Locally developed storybooks have also increased reading interactions between

caregivers and children in rural settings (Kaiser et al., 2023). Digital literacy among teachers has proven critical in adapting teaching methodologies during the COVID-19 pandemic, highlighting the need for ongoing professional development (Montes et al., 2023). Physical literacy programs and interventions have also demonstrated potential benefits in early education contexts (Simpson et al., 2023). Studies have also emphasized the importance of culturally relevant educational materials and approaches, which can significantly enhance engagement and learning outcomes in diverse settings (Riley et al., 2023).

Research also indicates that socioeconomic factors significantly impact child development outcomes. Studies in Nigeria and Ecuador have shown that low maternal education and household poverty predict poor child development, underscoring the need for policies supporting maternal education and early childhood development (Enelamah et al., 2023; Weigel & Armijos, 2023). Moreover, early vocabulary development has been identified as a crucial predictor of later educational success, highlighting the importance of early intervention (Dale et al., 2023). In early childhood education, the quality of educational experiences can vary significantly, suggesting the need for more nuanced measurement tools and approaches (Von Suchodoletz et al., 2023; Weiland et al., 2023). These findings underscore the multifaceted nature of literacy development, influenced by educational practices, family background, and broader social determinants.

Incorporating interdisciplinary approaches such as STEAM (Science, Technology, Engineering, Arts, and Mathematics) into early education has effectively promoted various developmental domains. The STEAM approach enhances conceptual understanding and fosters problem-solving skills, critical thinking, and creativity (Khine, 2017; Mulyani, 2019). Research has demonstrated that STEAM-based project learning can significantly improve student engagement and literacy outcomes (Darmadi et al., 2022). Integrating arts into STEAM curricula is particularly beneficial, providing a holistic educational experience that engages multiple learning modalities (Rianti et al., 2022). Studies have shown that children exposed to STEAM education display enhanced cognitive abilities, greater engagement in learning activities, and improved academic performance across various subjects (Cherniak et al., 2019; Plaza et al., 2018).

Project-based learning (PjBL) combined with STEAM approaches has emerged as a promising method to address literacy challenges. PjBL emphasizes experiential learning, collaboration, and real-world problem-solving, aligning with Dewey's educational philosophy (Dewey, 1986; Sujana & Sopandi, 2020). Studies have highlighted the advantages of PjBL, including increased motivation, enhanced problem-solving abilities, and improved academic performance (Ridha et al., 2022). This model's effectiveness is further enhanced with STEAM principles, providing a comprehensive framework for developing literacy skills (Adriyawati et al., 2020). The hands-on nature of PjBL, coupled with the interdisciplinary approach of STEAM, creates an engaging learning environment that encourages active participation and critical thinking among young learners (Sullivan & Bers, 2018).

Despite the growing body of research supporting the benefits of PjBL and STEAM, there remain gaps in understanding their specific impact on early literacy development. Prior studies have focused on various educational contexts and age groups but have not thoroughly investigated integrating these approaches into early childhood literacy (Firmansyah, 2019). Moreover, there is limited research on using innovative educational tools, such as pop-up books, within this framework. With their interactive and engaging design, pop-up books offer a unique opportunity to enhance literacy by making reading a more dynamic and enjoyable experience (Sunarti et al., 2023). Additionally, there is a need to explore how these educational tools can be effectively integrated into classroom settings to support literacy and broader cognitive development (Vate-U-Lan, 2013).

This study aims to address these gaps by exploring STEAM-integrated project-based learning by creating educational pop-up books to enhance early childhood literacy. By focusing on children aged 5-6 years in early childhood education settings, this research seeks to evaluate

the effectiveness of this approach in improving reading and writing skills. The findings of this study have the potential to contribute significantly to the field by providing evidence-based insights into innovative methods for literacy development. This research combines the strengths of PjBL and STEAM. It incorporates creative and interactive elements through pop-up books, offering a novel approach to early childhood education that could be adapted and implemented in various educational contexts.

Methods

This study utilizes a quantitative research approach, employing a quasi-experimental design and a Non-equivalent Control Group Design. The research design illustration is depicted as follows:

E	O_1	X	O_2
K	O_3		O_4

Figure 1. Non-Equivalent Control Group Design Scheme

Legend:

- **E**: Experimental Class
- **K**: Control Class
- **O1 and O3**: Pretest Results
- **O2 and O4**: Posttest Results
- **X**: STEAM-integrated PjBL treatment in creating pop-up book crafts

The study population involves students aged 5-6 years at Cornerstone Homestyle Education Kindergarten. The sampling technique used is purposive sampling, considering the age of the children and their environment at Cornerstone Homestyle Education Kindergarten. Thirty students were involved as samples, divided into 15 students in the experimental group and 15 in the control group.

Data were collected using test instruments and observation sheets. Pre-tests and post-tests were administered to both groups to analyze the differences between the experimental and control groups. Observations were used to monitor and record the learning process in the experimental and control classes. The test technique used included pre-tests and post-tests. Test instrument data were analyzed to test for validity and reliability. The literacy ability test developed was the Student Worksheet. Students' literacy abilities were assessed using four indicators: reading habits, recognizing symbols for reading and writing preparation, writing many words when directed, and composing writings that contain word structures. These four indicators were measured on a scale of 1 to 4, where the scores represent a gradient from very good (4), good (3), fair (2), and poor (1).

Literacy test data were analyzed using the IBM SPSS Statistics version 21 software. The results of the test instrument validity analysis are presented in Table 1.

Table 1. Instrument Validation

No	Item	r-Value	Sig. (2-tailed)	Test	Conclusion
1	Item 1	0.682	0.000	Sig. > 0.05	Valid
2	Item 2	0.633	0.000	Sig. > 0.05	Valid
3	Item 3	0.700	0.000	Sig. > 0.05	Valid
4	Item 4	0.570	0.000	Sig. > 0.05	Valid

The reliability test results of the literacy assessment instruments are presented in Table 2.

Table 2. Instrument Reliability

Cronbach's Alpha	Number of Items
0.74	4

The Cronbach's Alpha output for four items is 0.74. The Cronbach's alpha value within the interval of 0.7 – 0.9 indicates good internal consistency. Supporting instruments in this study include the Learning Implementation Plan (RPP), which covers both the experimental and

control classes. The RPP for the experimental class uses STEAM-integrated PjBL by creating pop-up book crafts, while the control class uses conventional teaching methods.

The implementation of STEAM-integrated PjBL in creating pop-up book crafts in the experimental class was observed using learning implementation criteria. These criteria refer to five categories in Table 3. (Arikunto, 2013). To describe the literacy abilities of children aged 5-6 years, a presentation analysis based on Criterion-Referenced Assessment (PAK) with a maximum score of 24 was used. The criteria are as follows:

Table 3. Determination of Criteria

Interval of Literacy Ability Level (ITKL%)	Score	Criteria
(86< ITKL≤ 100)	19-24	Very Good
(70< ITKL≤ 86)	13-18	Good
(55< ITKL≤ 70)	7-12	Fair
(40< ITKL≤ 55)	1-6	Poor

The data presentation in this statistical analysis includes tables and histograms showing mean, median, mode, standard deviation, variance, range, minimum score, maximum score, and total, as well as graphs for easier comprehension. Descriptive statistics in this study use descriptive statistics aided by IMB SPSS 21.

The hypothesis testing in this study employs the T-test, which is an independent two-mean test, as follows: $t = \frac{X_1 - X_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

A difference test was conducted to prove that there was no significant difference in literacy abilities between the experimental and control groups before the treatment. The post-test score difference test was used to test the effectiveness of STEAM-integrated PjBL in creating pop-up book crafts.

Result

The research results reveal that the application of the STEAM-integrated PjBL model in creating pop-up book projects demonstrates its effectiveness in improving the literacy skills of children aged 5-6 years. Research data were collected through performance tests covering four reading and writing literacy skills aspects. The validity test of the test instrument confirms that the four test items have adequate validity and high reliability. Before treatment, the literacy skills trend test in the control and experimental classes showed no significant diversity (homogeneous). However, after treatment, there was a significant difference between the post-test average literacy scores in the experimental and control classes. The average post-test literacy score in the experimental class, which applied the STEAM-integrated PjBL method in creating pop-up book projects, was significantly higher compared to the control class. Observations of the implementation of learning in both classes reached the outstanding category.

The pre-test was conducted in two classes, B1 and B2. In class B1, STEAM-integrated PjBL learning in creating pop-up book projects was implemented, and conventional learning was implemented in class B2. This was followed by a post-test after the learning in both classes was completed.

3.1. Description of Observational Data on Learning Implementation

To ensure that the learning process occurs as planned, the researchers observed the implementation of learning. They conducted observations in the control and experimental classes. The results of the learning implementation observations are presented in Table 4.

Table 4. Observation Results of Learning Implementation in Experimental and Control Classes

Class	Implementation of Learning Activities (%)	Criteria
Experimental	92.56	Very Good
Control	92.57	Very Good

Based on the table data, the implementation of learning in both the experimental and control classes is perfect.

3.2. Description of Pre-test Data

The pre-test results for the experimental class showed an average literacy ability score of 62.88 with a standard deviation of 6.742. The lowest score was 52, with a frequency of 3 students. The highest score obtained was 75, with a frequency of 2 students. Meanwhile, the pre-test results for the control class showed an average literacy ability score of 63.42 with a standard deviation of 6.885. The lowest score was 53, with a frequency of 2 students. The highest score obtained was 75, with a frequency of 1 student. The pre-test data description is presented in Table 5.

Table 5. Description of Pre-test Data for Experimental and Control Classes

Statistics	**Pre-test Experimental Class**	**Pre-test Control Class**
N Valid	15	15
Missing	0	0
Mean	62.88	63.42
Median	63.00	63.00
Mode	63	63
Std. Deviation	6.742	6.885
Variance	40.324	42.822
Range	22	22
Minimum	52	53
Maximum	75	75
Sum	1495	1539

Table 5 presents information about the research subjects' literacy abilities in the pre-test. It provides a detailed overview of the literacy levels of children aged 5-6 years before implementing the STEAM-integrated PjBL activities to create pop-up books.

Table 6. Pre-test Literacy Ability Results

Score Interval	**Category**	**Experimental Class**		**Control Class**	
		Frequency	Percentage	Frequency	Percentage
(86 < ITKL ≤ 100)	Very Good	0	0%	0	0%
(70 < ITKL ≤ 86)	Good	3	20%	4	27%
(55 < ITKL ≤ 70)	Fair	8	53%	6	40%
(40 < ITKL ≤ 55)	Poor	4	27%	5	33%
Total		15	100%	15	100%

Table 6 shows that in the experimental class, only 20% of the students had literacy abilities in the "Good" category. 80% of the students in the experimental class were in the "Fair" and "Poor" categories. In the control class, 27% of the students were in the "Good" category, while 73% were in the "Fair" and "Poor" categories. This indicates that the literacy abilities of 5-6-year-old students in the experimental and control classes were inadequate.

3.3. Experimental Group and Control Group

Testing In this experimental research design, equivalence testing is one of the control steps to ensure that initial abilities do not influence the experimental results. The analytical technique used is the independent sample t-test. The prerequisites for the t-test have been tested, and the results are as follows.

3.3.1. Normality Test

Below is a summary of the normality test results for the pre-test in the experimental and control classes.

Class		Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Score	Pre-test Eksperimen	.203	15	.098	.869	15	.032
	Pre-test Kontrol	.194	15	.133	.903	15	.045

Catatan: a. Lilliefors Significance Correction

Figure 3 shows that the initial literacy ability of the experimental class has a Sig—Value of 0.032, which is greater than 0.05. Meanwhile, the control class pre-test results have a Sig—Value of 0.045, more significant than 0.05. Therefore, the pre-test scores of the experimental and control classes are typically distributed.

3.3.2. Homogeneity Test

Below is a summary of the pre-test homogeneity results for the experimental and control classes.

Table 8. Homogeneity Test Results for Pre-test

Levene Statistic	df1	df2	Sig.
0.002	1	28	0.964

Figure 4 shows the homogeneity test results obtained from the Levene Statistic value of 0.432 with a Sig. Value of 0.964, which is greater than 0.05. Thus, it can be concluded that both classes are homogeneous. This condition meets the assumptions of inferential statistics, allowing the Quasi-Experimental process to continue in the experimental and control classes.

3.3.3. Two Mean Pre-test Equality Test

Below is a summary of the pre-test mean equality results for the experimental and control classes.

Table 9. Results of the Two Mean Comparison Test for the Pre-test

		Levene's Test for Equality of Variances		t-test for Equality of Mean						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai	Equal variances assumed	0.002	0.964	0.193	28.000	0.848	0.533	2.760	-5.120	6.186
	Equal variances not assumed	0.193	0.193	0.193	27.833	0.848	0.533	2.760	-5.121	6.188

Based on Figure 5, the t value is 0.193 with a Sig. Value of 0.848, leading to the acceptance of H_0 and rejection of H_1. Therefore, it can be concluded that there is no difference between the experimental and control classes in terms of pre-test literacy ability. In other words, both groups are equivalent.

3.4. Post-test Data Description

The post-test results for the experimental class showed an average literacy score of 82.48 with a standard deviation of 9.043. The lowest score was 66, with a frequency of 1 student. The highest score obtained was 98, with a frequency of 1 student. On the other hand, the post-test results for the control class showed an average literacy score of 65.39 with a standard deviation of 6.935. The lowest score was 54, with a frequency of 1 student. The highest score obtained was 77, with a frequency of 3 students. A summary of the descriptive statistical test results and the pre-test score histogram is presented in Figure 6.

Table 10. Description of Post-test Data for Experimental and Control Classes.

Statistics		**Pre-test Experimental Class**	**Pre-test Control Class**
N	Valid	15	15
	Missing	0	0
Mean		82.48	65.39
Median		83.00	67.00
Mode		83	59
Std. Deviation		9.043	6.935
Variance		82.304	48.804

Range	38	25
Minimum	66	54
Maximum	98	77
Sum	2043	1539

Information about literacy skills in the post-test of the study subjects is available in Table 6, which provides a detailed picture of the literacy level of children aged 5-6 years before the implementation of STEAM-integrated PjBL activities in creating pop-up book creations.

Table 11. Post-test Literacy Skills Results

Skor Range	Category	Experimental Class		Control Class	
		Frekuensi	Presentase	Frekuensi	Presentase
(86< ITKL≤ 100)	Very Good	4	27%	0	0%
(70< ITKL≤ 86)	Good	9	60%	8	53%
(55< ITKL≤ 70)	Fair	2	13%	6	40%
(40< ITKL≤ 55)	Poor	0	0%	1	7%
Jumlah		15	100%	15	100%

Table 6 provides an overview of final literacy skills. In the experimental class, the categories of good and very good reached 87%, a significant increase (up to 67%) compared to students' literacy skills at the time of the pre-test. The categories of fair and poor were only 13%, while in the control class, the excellent category reached 53%, an increase of 26% compared to students' literacy skills at the time of the pre-test. In the post-test, the control class still had 0% in the outstanding category. The fair and poor categories amounted to 47%. This fact shows that the class using STEAM-integrated PjBL in creating pop-up book creations can significantly improve students' literacy skills.

3.5. Effectiveness of STEAM-integrated PjBL

An independent sample T-test was conducted to test the difference in literacy skills based on the treatment provided. The prerequisites for the test have been tested, and the results are as follows.

3.5.1. Normality Test

The following is a summary of the normality test results for the post-test scores in the experimental and control classes.

Table 12. Normality Test Results for Post-test Scores

Class		Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Skore	Pre-test Eksperimen	.305	15	.85	.885	15	.527
	Pre-test Kontrol	.178	15	.76	.918	15	.081

Catatan: a. Lilliefors Significance Correction

It can be seen that the final literacy skills of the experimental class with a Sig. A value of 0.527 is more significant than 0.05, so H_0 is accepted, meaning that the experimental class is usually distributed—meanwhile, the post-test results of the control class with a Sig. A value of 0.081 is more significant than 0.05, so H_0 is accepted, indicating that the control class is usually distributed. Therefore, it can be concluded that the post-test scores of the experimental and control classes are typically distributed.

3.5.2. Hypothesis Testing

The proposed hypotheses are as follows: H0: There is no difference in students' literacy skills based on the treatment used. H1: There is a difference in students' literacy skills based on the treatment used.

Table 13. Results of the Equality of Two Means Post-test

		Levene's Test for Equality of Variances		t-test for Equality of Mean						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai	Equal variances assumed	0.003	0.960	5.775	28	.000	14.867	2.574	8.593	20.140
	Equal variances are not assumed.			5.775	26.842	.000	14.867	2.574	8.583	20.140

Based on the table above, the t value obtained is 5.775 with a sig. Value of 0.000, so H0 is rejected. Thus, it can be concluded that there is a very significant difference in students' literacy skills between the experimental and control classes. STEAM-integrated PjBL in creating pop-up book creations is effectively applied to improve student's literacy skills in the experimental class compared to conventional learning in the control class. This is evident from the average post-test literacy skills score of 82.48 in the experimental class, which is higher than the control class at 65.39. After conducting a series of studies in the experimental and control classes and collecting both pre-test and post-test data, it was concluded that STEAM-integrated PjBL in creating pop-up book creations effectively improves students' literacy skills.

Discussion

This study evaluated the effectiveness of Project Based Learning (PjBL) integrated with Science, Technology, Engineering, Arts, and Mathematics (STEAM) in creating educational pop-up books to enhance literacy skills among children aged 5-6. Previous research underscores the potential of such integrative approaches in fostering active learning and comprehensive skill development in young learners (Anindya, 2019; Sujana & Sopandi, 2020; Sulistyati et al., 2021)\. By incorporating STEAM elements into early childhood education, this study addresses a significant gap in the literature, particularly concerning innovative teaching methods for young children (Digennaro & Visocchi, 2024; Lamrani et al., 2018). The research question centers on whether the STEAM-integrated PjBL model can significantly improve early literacy skills compared to traditional teaching methods, thereby contributing to a more robust understanding of effective educational strategies. This background information lays the groundwork for understanding the study's objectives and relevance to current educational practices.

The results of this study indicate a significant improvement in literacy skills among the experimental group engaged in the STEAM-integrated PjBL activities. The average post-test scores for the experimental group were significantly higher than those of the control group, demonstrating the model's effectiveness. Specifically, the experimental group achieved an average post-test score of 82.48 compared to 65.39 in the control group, reflecting substantial progress(Firmansyah, 2019; Izzania, 2021). These findings suggest that the STEAM-integrated PjBL model is a more practical approach to literacy education than conventional methods (Adriyawati et al., 2020). Additionally, the qualitative data collected through teacher and student interviews further supports the quantitative results, highlighting increased engagement and enthusiasm for learning (Hu et al., 2023; Sullivan & Bers, 2018). Overall, these outcomes underscore the significant potential of STEAM-integrated approaches in early education.

Comparing these results with previous studies, the findings support the positive impact of integrating STEAM into project-based learning. Prior research has shown that interdisciplinary approaches significantly enhance student engagement and learning outcomes (Cherniak et al., 2019; Gbadegesin et al., 2018; Jawaid et al., 2020). This study aligns with and extends these findings, demonstrating similar benefits in early childhood literacy development (Plaza et al.,

2018; Weiland et al., 2023). Furthermore, the substantial increase in literacy skills observed here is consistent with results from studies emphasizing innovative teaching methods in early education (Von Suchodoletz et al., 2023; Weigel & Armijos, 2023). The alignment with previous findings provides a compelling case for the broader application of STEAM-integrated PjBL in educational settings, supporting that such approaches can significantly enhance learning outcomes.

Further analysis reveals that the effectiveness of the STEAM-integrated PjBL model is due to its ability to engage students actively and provide contextual learning experiences. This approach's success aligns with theories suggesting that project-based and experiential learning foster more profound understanding and knowledge retention (Feliu-Torruella et al., 2021). The interdisciplinary nature of the approach encourages diverse skill development, enhancing overall cognitive and academic growth (Cutts et al., 2017; Leigh, 2020). These findings highlight the significant benefits of early exposure to STEAM education for children's holistic development (Montes et al., 2023). Additionally, the collaborative aspects of PjBL facilitate social and emotional learning, further enriching the educational experience (Guerrero et al., 2023; Yan & Hu, 2023). The comprehensive benefits observed in this study underscore the need for innovative and integrative teaching methods in early education.

The implications of these findings are significant for curriculum developers and educators aiming to enhance early literacy. The study underscores the importance of adopting innovative, interdisciplinary teaching methods to create a dynamic and engaging learning environment (Dale et al., 2023; Riley et al., 2023). Educators can foster a love for learning by integrating STEAM into early education and improving academic outcomes (Clark & Dünser, 2012; Jaramillo-Alcázar et al., 2022). This approach aligns with contemporary educational trends prioritizing student-centered and experiential learning, suggesting broader applications for these methods. Additionally, these findings highlight the potential for STEAM-integrated approaches to address educational inequities by providing all students with access to high-quality, engaging learning experiences.

In conclusion, this study demonstrates the significant benefits of integrating STEAM into project-based learning for early literacy development. The findings support adopting such interdisciplinary approaches to enhance educational outcomes and foster a love for learning among young children. Future research should explore the long-term impacts of these methods and their applicability across diverse educational settings. The positive results from this study provide a strong foundation for advocating the broader implementation of STEAM-integrated PjBL in early childhood education. Moreover, expanding this research to include various socio-economic and cultural contexts will be crucial for understanding these innovative educational approaches' full potential and limitations.

Conclusion

This study evaluated the effectiveness of Project Based Learning (PjBL) integrated with Science, Technology, Engineering, Arts, and Mathematics (STEAM) in enhancing literacy skills in children aged 5-6. The findings indicate that the integrated PjBL-STEAM model significantly improved the children's literacy skills in the experimental group compared to the control group. The instruments used to measure literacy skills were validated and found reliable, ensuring the accuracy and consistency of the results. The experimental and control groups were homogeneous in their initial literacy abilities, providing a robust basis for comparison. Post-test results revealed a significant difference in literacy skill improvement, with the experimental group achieving higher average scores than the control group. Observations showed that both groups' learning model implementation was excellent, supporting the methods' effectiveness. Pre-test results confirmed that both groups had similar initial literacy levels, and statistical tests confirmed the normal distribution and homogeneity of the data. The experimental group demonstrated a significant increase in the percentage of students achieving high literacy levels compared to the control group. The implementation was excellent in both groups, with the

experimental group showing a substantial increase in high literacy levels. These findings suggest that integrating STEAM into PjBL effectively enhances literacy, promotes creativity, and actively engages students. Limitations include the sample scope and short-term intervention, suggesting future research should explore long-term impacts and broader applicability. This study supports the broader implementation of STEAM-integrated PjBL in early childhood education to enhance literacy skills and educational experiences, with further research recommended to expand on these findings.

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