



Integrating Local Culture-Based STEAM-PJBL to Enhance Competence in Fine Motor Skill Learning Design: A Development Study

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ABSTRACT

The limited availability of learning media that integrate local cultural contexts within STEAM-based instruction remains a challenge in optimizing fine motor skill development in childhood education. This study aims to develop a Local Culture Oriented STEAM-Project-Based Learning (STEAM-PJBL) module and examine its feasibility, practicality, and effectiveness in enhancing fine motor skills among children aged 4–5 years. The study employed a Research and Development approach by adapting the Borg and Gall model into six stages: needs analysis, instructional design, prototype development, expert validation, product revision, and limited field testing. Participants included one content expert, one media expert, early childhood teachers, and eight children aged 4–5 years. Data were collected through observation, interviews, questionnaires, and pre- and post-tests of fine motor skills. The findings show high feasibility, with content validity of 91.6% and media validity of 89%. Teacher responses indicated high practicality at 92%. The module effectively improved children's fine motor skills, as shown by a significant increase in mean scores from 67.0 to 80.75 ($p < 0.05$). The novelty of this study lies in integrating local cultural contexts across all stages of STEAM-PJBL design, positioning fine motor development as a core learning outcome in early childhood education.

INTRODUCTION

Early childhood education plays a crucial role in establishing the developmental foundation for children, including the enhancement of creative thinking skills (Sari & Agustriana, 2024). At this stage, children experience a sensitive period in which all developmental domains cognitive, social-emotional, language, physical, moral, and artistic grow rapidly and interact with one another. Therefore, a structured, responsive, and experience-rich learning environment is essential to ensure that every aspect of children's development is optimally supported. High-quality early childhood education not only strengthens creative and critical thinking skills but also fosters communication skills, emotional regulation, independence, fine and gross motor skills, and social adaptability. Consequently, early childhood education functions as a holistic foundation that nurtures children's overall growth, preparing them not only for academic readiness but also for meaningful participation and successful adjustment in everyday life.

Fine motor skills refer to the ability to coordinate small muscles of the hands and fingers to perform precise, controlled, and purposeful movements, such as grasping, cutting, drawing, and manipulating objects (Vinter, A., & Lemoine, 2020). In early childhood, particularly at 4–5 years, fine motor Development plays a critical role in preparing children for academic tasks and daily functional activities. From a developmental perspective, Piaget explains that children in the preoperational stage



construct knowledge through direct interaction with concrete objects, making fine motor activities essential for supporting symbolic thinking and early problem-solving (Piaget, J., & Inhelder, 1969). Papalia et al. further emphasize that fine motor skills develop gradually through repeated and meaningful experiences that integrate perceptual, cognitive, and motor processes (Papalia, D. E., Martorell, G., & Feldman, 2021).

The development of fine motor skills has significant implications for children's overall growth (Pica, 2020). Well-developed fine motor abilities support early writing readiness, tool use, hand-eye coordination, and self-care skills, while also contributing to cognitive regulation, independence, and learning persistence (Jarus, T., & Gerlach, 2019). For children aged 4–5 years, adequate stimulation of fine motor skills is crucial, as this period represents a sensitive phase for strengthening hand control and coordination required for more complex learning tasks in later stages (Sari & Agustriana, 2024). Fine motor skill development is a fundamental component of learning readiness and independence in children aged 4–5 years, as it not only supports physical abilities such as writing readiness and hand-eye coordination but also contributes to cognitive regulation, learning persistence, and children's preparedness to engage in more complex learning tasks at later developmental stages.

However, empirical conditions in early childhood education indicate that fine motor development has not yet been optimally facilitated. Learning activities intended to stimulate fine motor skills are often limited to worksheet-based tasks, tracing, coloring, or repetitive paper-and-pencil exercises, which provide minimal opportunities for exploration, creativity, and problem-solving through coordinated hand movements (Pica, 2020). In addition, learning media frequently lack contextual relevance and fail to connect children's learning experiences with their sociocultural environment, reducing engagement and motivation for sustained fine motor practice (Sari et al., 2025). Although STEAM-based learning has gained increasing attention in early childhood education, many implementations emphasize cognitive outcomes related to science and technology concepts. At the same time, project-based processes and fine motor skill development receive limited systematic attention (Vinter, A., & Lemoine, 2020).

These challenges highlight the need for an instructional approach that not only supports fine motor development but also provides meaningful, hands-on, and contextually relevant learning experiences. In this regard, Local Culture-Based STEAM–Project-Based Learning (STEAM-PJBL) offers a promising solution. The lack of hands-on activities, minimal cultural relevance, and fragmented fine-motor stimulation can be addressed through STEAM-PJBL activities that integrate local cultural materials, tools, and practices familiar to children, enabling active exploration and continuous fine-motor engagement within authentic learning contexts.

Local Culture-Based STEAM-PJBL is defined as an instructional approach that integrates Science, Technology, Engineering, Arts, and Mathematics through project-based learning activities grounded in children's local cultural contexts. This approach emphasizes learning by doing, problem-solving, and collaborative projects, while situating learning experiences within culturally meaningful environments. Its advantages include increased learning relevance, higher child engagement, richer hands-on experiences, and systematic opportunities to enhance fine motor coordination through the design, construction, and manipulation of culturally familiar materials. Such characteristics align closely with the developmental needs of children aged 4–5 years (Prahartiwi et al., 2025).

Several previous studies have examined STEAM learning, project-based learning, and cultural integration in education. Rahmadani et al. (2025) explored the application of STEAM approaches in social and natural science learning grounded in local wisdom; however, the study focused on subject implementation rather than fine-motor development or early childhood contexts (Rahmadani et al., 2025). Mathilde Muhu et al., (2024) Loose parts–based STEAM learning integrated with local wisdom provides contextual and meaningful learning experiences for young children, enabling flexible exploration of environmental materials and fostering holistic developmental stimulation while strengthening children's understanding of and attachment to their local culture (Mathilde Muhu et al., 2024). Prasetyo (2024) demonstrated that project-based learning using loose parts could stimulate children's fine motor coordination, yet the study did not integrate STEAM principles or cultural contexts systematically (Prasetyo, 2024). Meanwhile, Tyas et al. (2025) reported positive effects of STEAM-based learning on fine motor development, but without employing a structured project-based learning



framework (Tyas et al., 2025). Dejarnette (2018) highlighted the potential of early childhood STEAM initiatives but primarily emphasized cognitive and collaborative outcomes rather than fine motor skills (Dejarnette, 2018).

Based on this analysis, the novelty of this study lies in the systematic integration of local culture-based STEAM-PJBL into a learning module specifically designed to enhance the fine motor skills of children aged 4–5 years, while simultaneously strengthening teachers' competence in the design of fine motor skill learning. Unlike previous studies, this research positions fine motor development as a central learning objective and embeds cultural context, STEAM elements, and project-based processes into a unified instructional design.

Therefore, this study aims to develop and evaluate the feasibility, practicality, and effectiveness of a Local Culture-Based STEAM-PJBL module for enhancing the fine motor skills of children aged 4–5 years and supporting early childhood educators in designing meaningful, developmentally appropriate fine motor learning experiences. The module integrates Bengkulu cultural elements, such as kain besurek stamping and simple weaving patterns, which require precise finger control, coordinated hand movements, and tool manipulation, thereby making learning activities meaningful and contextually relevant. The specific objectives of this study are to: (1) develop a STEAM-PJBL learning module that integrates local cultural practices into fine motor skill learning activities; (2) examine the feasibility and practicality of the module through expert validation and teacher responses; and (3) evaluate its effectiveness based on pre- and post-assessments of children's fine motor skill development.

By embedding culturally grounded, hands-on activities within a structured STEAM-PJBL framework, this study strengthens the theoretical linkage between project-based STEAM learning and fine motor skill development in early childhood. Given the limited number of studies that systematically integrate STEAM-PJBL with local culture-based fine motor activities, this research addresses an important gap and is expected to contribute to the advancement of innovative and culturally responsive early childhood learning models.

METHOD

This study developed a local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module to enhance fine motor skills in early childhood, using a Research and Development (R&D) approach adapted from Borg & Gall. This R&D approach was chosen because the study aimed not only to examine effectiveness, but also to develop, validate, and refine an instructional product. While the original model includes 10 stages, this study used a 6-stage modification (needs analysis, media design, prototype development, expert validation, product revision, and limited trial) due to time and resource constraints, ensuring a systematic yet manageable research flow. This adaptation ensured a systematic yet manageable flow from initial analysis to small-scale trials. The steps are illustrated in Figure 1 (Gall, M. D., Gall, J. P., & Borg, 2007).

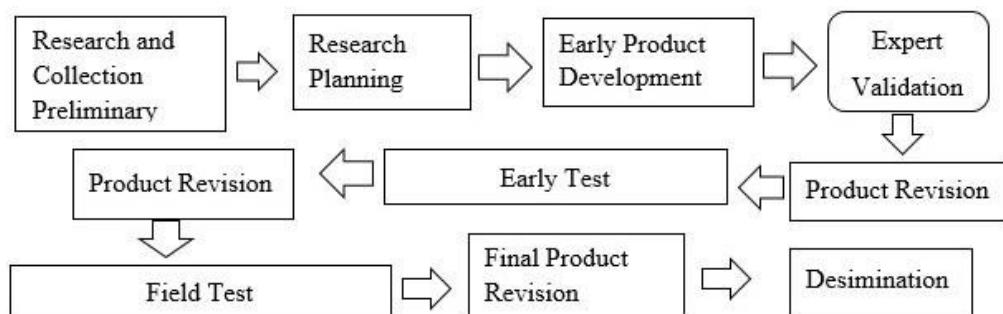


Figure 1. Research and Development (R&D) Model by Borg and Gall

Figure 1 presents the Research and Development (R&D) procedure adapted from the Borg and Gall model applied in this study. The model was modified into a six-stage process to accommodate the study's scope and context, consisting of needs analysis, media design, prototype development, expert validation, product revision, and limited field testing. This procedural framework guided the systematic



development and evaluation of the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module. Referring to Figure 1, the development process began with a needs analysis conducted through classroom observations, teacher interviews, and a review of relevant literature to identify limitations in existing fine motor learning practices. The media design stage focused on planning STEAM–PjBL activities that integrate Bengkulu's local cultural elements, such as Batik Besurek and simple traditional crafts. A prototype module was then developed and evaluated by expert validators to assess content validity, feasibility, and pedagogical alignment. Based on validation results, revisions were made to improve instructional clarity and alignment with fine motor skill objectives. The revised module was subsequently implemented in a limited trial involving early childhood learners and teachers, with data collected through pre–post assessments, questionnaires, and structured observations to evaluate its practicality and effectiveness.

As part of the limited field trial phase in the Research and Development (R&D) process, the study involved 8 children aged 4–5 years (4 boys and 4 girls) from a single PAUD classroom at PAUD Lab School UNIB, Bengkulu, along with one early childhood teacher and two expert validators (one media specialist and one content specialist). The limited trial was conducted in an urban PAUD setting equipped with standard classroom facilities that support hands-on, STEAM-based project learning activities. All procedures complied with ethical standards for research involving young children.

Children's fine motor skills were assessed using a structured observation sheet developed based on early childhood fine motor development indicators. The structure of the observation instrument is presented in Table 1. The instrument focused on the fine motor skills variable and consisted of several aspects, including hand–eye coordination, fine motor control, fine motor coordination, and finger dexterity.

Table 1. Observation Sheet Grid

Variable	Aspect	Indicator
Fine Motor Skills	Hand-eye Coordination	1. Ability to hold a pencil correctly 2. Ability to cut paper along a line
	Fine Motor Control	3. Drawing basic shapes such as circles, squares, and triangles
	Fine Motor Coordination	4. Stacking blocks or assembling small objects
	Finger Dexterity	5. Manipulating small objects like beads, buttons, and zippers

As shown in Table 1, each aspect of fine motor skills was operationalized into observable and measurable behavioral indicators appropriate for children aged 4–5 years. These indicators enabled systematic and objective observation of children's fine motor performance during learning activities. The observation results were used to capture changes in children's fine motor skills before and after the implementation of the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module.

Data analysis combined quantitative and qualitative approaches (Sugiyono, 2016). Quantitative data obtained from the observation sheets were analyzed using paired sample t-tests in SPSS version 16 to examine improvements in children's fine motor skills before and after the intervention. Data normality was tested using the Shapiro–Wilk test ($p > 0.05$). Instrument reliability was examined using Cronbach's Alpha, yielding a coefficient of 0.89, which indicates high internal consistency.

Qualitative data collected from teacher observations and interviews were analyzed using thematic analysis through open, axial, and selective coding to identify recurring themes related to instructional clarity, child engagement, and learning interest. Quantitative and qualitative findings were then triangulated to ensure that statistically significant improvements in children's fine motor skills were supported by observable classroom interactions and teacher feedback. The triangulated results were used as the basis for refining the module to better align learning activities, content, and instructional approaches with children's developmental needs. Teacher and expert validator feedback on the content quality, media design, and practicality of the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module was collected using a 4-point Likert scale, as presented in Table 2.

Table 2. Likert Scale

No	Quantitative Analysis	Score
1	Strongly Agree	4



1	Strongly agree	4
2	Agree	3
3	Disagree	2
4	Strongly disagree	1

Based on Table 2, higher scores indicated stronger agreement from teachers and expert validators regarding the feasibility, content quality, and practicality of the developed STEAM-PjBL module. The feasibility of the local culture-based STEAM-PjBL learning module, which integrates science literacy to stimulate fine motor skills, was evaluated using a validation sheet completed by two expert validators. The scores provided by the validators were calculated as percentages using the following formula:

$$\text{Percentage} = (\text{Total Score Obtained from validator} / \text{Maximum Possible Score from validator}) \times 100$$

The resulting percentage scores were interpreted using the feasibility criteria presented in Table 3. Based on Table 3, the level of module feasibility was determined by categorizing the percentage scores into four criteria, ranging from not feasible to highly feasible. Trials involving children and teachers were conducted to assess their responses to the developed product. Trial data were collected using a Likert scale ranging from 1 to 4 and analyzed using the following formula:

$$\text{Percentage} = (\text{Total Score} / \text{Maximum Score}) \times 100$$

Table 3. Eligibility Criteria

Percentage Score (%)	Interpretation
85 – 100	Highly feasible
70 – 84	Feasible
50 – 69	Moderately feasible
0 – 49	Not feasible

The results of the trials were interpreted using the criteria presented in Table 4.

Table 4. Trial Percentage

Presentation Score	Interpretation
0- 25	Poor
26 – 50	Fair
51 – 75	Good
76 -100	Excellent

Based on Table 4, the effectiveness and acceptability of the developed module from the perspectives of children and teachers were classified into four levels: poor, fair, good, and excellent.

RESULT AND DISCUSSION



In the initial phase of the study, problem identification revealed a lack of engaging and interactive learning media in early childhood classrooms. Traditional methods often led to reduced engagement, as noted by one teacher below.

“Many children lose focus quickly during repetitive tasks and prefer hands-on activities,”

These findings highlighted the need for more innovative instructional designs. In the second stage, a comprehensive literature review emphasized the integration of local cultural elements into early childhood learning materials. Previous studies have shown that culturally relevant activities can strengthen children's connection to the content and improve engagement and learning outcomes (Munawwaroh, A., Hasanah, I., & Wulandari, 2023). Interviews with teachers indicated that, although some interactive media were used, locally rooted STEAM-PJBL designs had not yet been implemented. Consequently, a learning design integrating local culture-based STEAM-PJBL was developed to enhance children's fine motor skills through project-based learning activities.

The learning design was reviewed and evaluated by experts in media, pedagogy, and early childhood education. The results from the expert evaluations indicated that the learning design was valid. Overall, the expert evaluation demonstrated strong alignment with pedagogical standards and confirmed the design's feasibility in early childhood learning contexts. The media experts assessed the learning design based on the clarity of the materials, the appropriateness of integrating STEAM-PJBL principles, and the use of local cultural elements. The design received a score of 56 out of 60, reflecting its high feasibility and alignment with educational standards. Furthermore, the media expert recommended revising the book cover to provide a clearer, more accurate representation of Bengkulu's local culture (Figure 2). Likewise, the material expert suggested expanding the content to strengthen the culturally based stimulation components, ensuring it becomes more comprehensive and remains aligned with the intended learning objectives.

Based on Table 5, the media expert evaluation shows that the developed module performed well across all assessed criteria. The integration of STEAM-Project-Based Learning (STEAM-PjBL) achieved the maximum score (12/12), indicating that STEAM elements were fully embedded in the project-based activities. Cultural relevance obtained a score of 14 out of 15, demonstrating strong incorporation of local cultural elements. Pedagogical appropriateness received a score of 15 out of 16, suggesting that the learning objectives, activity design, and instructional strategies are well suited to children aged 4–5 years. Meanwhile, the visual and instructional design criterion scored 14 out of 17, indicating good visual quality and instructional clarity, with minor aspects identified for further improvement. Overall, the total score of 56 out of 60 reflects a high level of quality in terms of media presentation and instructional design.

Table 5. Media Expert Evaluation Results

Criteria	Indicator Items	Score Acquisition	Max Score
Integration of STEAM-PJBL	1, 2, 3	12	12
Cultural Relevance	4, 5, 6	14	15
Pedagogical Appropriateness	7, 8, 9	15	16
Visual and Instructional Design	10, 11	14	17
Total Score		56	60

Pedagogical Expert Evaluation

The material experts assessed the learning design's content alignment with early childhood educational goals, including its ability to foster fine motor skill development and engage children through project-based learning activities. The learning design received a score of 34 out of 36, indicating strong pedagogical alignment.

Table 6. Pedagogical Expert Evaluation Results

Criteria	Indicator Items	Score Acquisition	Max Score
Content Accuracy and Relevance	1,2,3	12	12
Appropriateness for Fine Motor Skills	4,5,6,7	14	16
Suitability for Project-Based Learning	8,9	6	8
Total Score		34	36



Based on Table 6, the pedagogical expert evaluation indicates that the learning design demonstrates strong alignment with early childhood educational goals. Content accuracy and relevance achieved the maximum score (12/12), confirming that the material is accurate and developmentally appropriate. The appropriateness for fine motor skill development obtained a score of 14 out of 16, showing that the activities effectively support fine motor stimulation with minor areas for refinement. The suitability for project-based learning scored 6 out of 8, indicating that the project structure is generally appropriate, although further strengthening of project guidance may be beneficial. Overall, the total score of 34 out of 36 reflects strong pedagogical quality of the developed learning design.

Before Revision	After Revision
SEBELUM	SESUDAH
<ul style="list-style-type: none">1. KATA PENGANTAR2. DAFTAR ISI3. BAB 1 Pendahuluan4. BAB 2 Kajian Teori5. BAB 3 Metode Pengembangan6. BAB 4 Hasil Pengembangan7. BAB 5 Validasi Ahli8. BAB 6 Uji Coba Produk9. BAB 7 Revisi Produk10. BAB 8 Produk Akhir11. DAFTAR PUSTAKA12. LAMPIRAN <ul style="list-style-type: none">1. KATA PENGANTAR2. DAFTAR ISI3. BAB 1 Pendahuluan4. BAB 2 Kajian Teori5. BAB 3 Metode Pengembangan	<ul style="list-style-type: none">1. KATA PENGANTAR2. DAFTAR ISI3. BAB 1 PENGANTAR MODUL CULTURA STEAM KIDS<ul style="list-style-type: none">1. Latar Belakang2. Tujuan Pembelajaran3. Sasaran Pengguna4. Prinsip STEAM untuk PAUD5. Budaya Lokal Bengkulu (Batik Besurek, Lantung, Anyaman)4. BAB 2. KONSEP DASAR MOTORIK HALUS<ul style="list-style-type: none">2.1 Pengertian Motorik Halus2.2 Indikator Perkembangan2.3 Peran Budaya Lokal dalam Motorik Halus2.4 Peran Guru dalam Fasilitasi Aktivitas3.5 Mini Batik Besurek3.6 Anyaman Kotak Bemkulu3.7 Kain Lantung Art5. Capaian Pembela

Figure 2. Before and After Revision

Teacher Feedback and Feasibility

The learning design was also evaluated by teachers, who provided valuable feedback on its practical feasibility and effectiveness. Teachers from PAUD Lab School UNIB highlighted the module's clear instructional objectives, engaging activities, and strong cultural relevance, which likely contributed to its effectiveness in maintaining children's attention and participation. The activities designed to support fine motor skills were generally effective, though some tasks could be further refined to maximize skill development. Overall, teacher evaluations indicate that the module is both culturally appropriate and pedagogically sound, with particular strength in engagement and contextual alignment.



Table 7. Teacher Feedback Results

Criteria	Indicator Items	Score Acquisition	Max Score
Cultural and Contextual Relevance	1,2,3	12	12
Effectiveness in Engaging Students	4,5,6	16	16
Suitability for Fine Motor Skills	7,8,9,10,11	20	24
Total Score		48	52

Based on Table 7, teacher feedback shows that the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module is highly practical and effective for classroom implementation. The cultural and contextual relevance criterion achieved the maximum score (12 out of 12), indicating strong alignment between the learning activities and the children's sociocultural environment. The effectiveness in engaging students criterion also reached the maximum score (16 out of 16), demonstrating that the module successfully promotes active participation and sustained learning interest. The suitability for fine motor skills criterion obtained a score of 20 out of 24, suggesting that the module effectively supports fine motor development, although minor adjustments may be needed to accommodate variations in children's motor abilities. Overall, the total score of 48 out of 52 reflects a very positive teacher response regarding the practicality, engagement level, and developmental appropriateness of the developed module.

Product Trial and Effectiveness

A small-scale product trial was conducted with eight children from Group A at Lab School Kindergarten to evaluate the effectiveness of the developed learning design, as presented in Table 8.

Table 8. Results of Child Trial Before and After Implementing the Learning Design

Name	Pre-Test Score	Post-Test Score	Category
A	15	18	Excellent
B	13	18	Excellent
C	15	18	Excellent
D	16	18	Excellent
E	13	17	Good
F	17	19	Excellent
G	12	16	Good
H	14	17	Good
Average	67.00%	80.75%	Excellent

As shown in Table 8, all children demonstrated higher post-test scores compared to their pre-test scores, indicating consistent improvement after the implementation of the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module. The average score increased from 67.00% in the pre-test to 80.75% in the post-test, with pre-test scores ranging from 60% to 75% and post-test scores ranging from 80% to 95%. This improvement reflects enhanced fine motor skills and increased cognitive engagement during learning activities.

To examine whether the observed improvement was statistically significant, a paired samples t-test was conducted. The results showed a significance value of $p = 0.001$ ($p < 0.05$), indicating a statistically significant increase in children's fine motor skill scores following the intervention.

Table 9. Paired Samples Test Results

Pair	Mean Difference	Std. Deviation	t	Df	Sig. (2-tailed)
Pre-Test - Post-Test	-2.93750	5.789	-9.651	7	0.001

As presented in Table 9, the paired samples t-test results indicate a statistically significant difference between pre-test and post-test scores. The mean difference of -2.94 reflects an overall



increase in children's scores following the implementation of the learning design. With a *t* value of -9.651 , $df = 7$, and a significance level of $p = 0.001$ ($p < 0.05$), the findings confirm that the local culture-based STEAM–Project-Based Learning (STEAM-PjBL) module had a significant effect on improving children's fine motor skills. These results provide empirical evidence that the observed learning gains were not due to chance but resulted from the intervention.

The findings of this research strongly support the effectiveness of integrating local culture-based STEAM-PjBL activities into early childhood education for enhancing fine motor skills. Results from classroom trials, expert evaluations, and teacher feedback indicate that combining local cultural elements with STEAM principles not only engages children but also fosters the development of essential cognitive and motor skills. Specifically, children showed improvement from 67% to 80.75% in fine motor skill scores, with the most notable gains observed in hand-eye coordination and finger dexterity. These findings are consistent with similar international studies, such as those by Yilmaz and Cavas (Yilmaz, R. M., & Cavas, 2018) and Hsu et al. (Hsu, P.-S., Ching, Y.-H., & Grabowski, 2020), which reported that culturally relevant, hands-on STEAM activities effectively enhance motor skill development in young children.

The integration of local culture, such as Batik Besurek patterns, clay figurines, and simple bamboo models, provides meaningful and contextually relevant tasks that require precise hand movements and sustained attention. These activities support motor control by engaging children in repetitive, fine-grained manipulations—cutting, shaping, assembling, and weaving—which strengthen small muscle coordination. This mechanism explains why culturally grounded craft activities specifically improve fine motor skills, a point that was not fully addressed in the original discussion. Similar findings were reported by Munawwaroh, Hasanah, and Wulandari (2023), showing that children are more motivated and engaged when learning resonates with their own cultural backgrounds (Munawwaroh, A., Hasanah, I., & Wulandari, 2023).

The success of the module also supports constructivist learning theory, which emphasizes active engagement with the environment, and Vygotsky's social-cultural theory, highlighting the role of culture and social interaction in cognitive and motor development (Vygotsky, 1978). Children engaged in hands-on tasks such as shaping clay figurines, weaving mats, and assembling bamboo models, all of which require fine manipulation and problem-solving, reinforcing both cognitive and motor growth. Teachers' feedback and expert validation confirmed that these activities not only stimulated skill development but also promoted creativity, attention to detail, and collaborative learning.

Modifications based on expert input including enhanced visual design, clearer instructions, and improved sequencing of activities underscore the importance of iterative design in educational product development (Prahartiwi , M., Mudiono, A., Samawi, A., Arifin, I., 2025). Iterative refinement allows educators to identify and address potential difficulties, ensuring that learning materials are developmentally appropriate and engaging for children (Azizah, E. M., Yuhasriati, Y., Khoiriyah, K., Rosmiati, R., & Mandira, 2023). Enhanced instructional design supports children's sustained engagement and comprehension during STEAM-based learning activities (Rahayu, E. Y., Nurani, Y., & Meilanie, 2023). Developmentally appropriate materials that integrate creative tasks improve children's active participation and motivation (Fitriani et al., 2025). By carefully tailoring content and structure, these modifications contribute to a more effective and enjoyable learning process for young learners. Overall, these refinements collectively enhance the quality and effectiveness of STEAM learning experiences for children, ensuring they are both engaging and educational.

Resource accessibility and structured planning have been shown to influence the success of STEAM activities in PAUD settings (Isnanningrum, I., & Marliani, 2025). Contextually relevant, hands-on STEAM experiences positively affect engagement and skill acquisition in young learners (Salma et al., 2023). Providing children with familiar materials linked to their cultural environment can increase participation and make learning more meaningful (Azizah et al., 2023). However, sufficient instructional time and teacher readiness remain significant factors in optimal implementation (Hapidin et al., 2025). Teachers' ability to scaffold learning and adapt activities to the pace of the class plays a crucial role in facilitating understanding and skill mastery (Rahayu et al., 2023). Taken together, these factors emphasize that both material and human resources are key determinants of successful STEAM-based learning.



Despite these positive outcomes, unexpected results were minimal, indicating that the module mostly functioned as intended, but variability in child responses warrants further investigation. Limitations of this study (Prahartiwi et al., 2025) include the small sample size ($n = 8$) and short trial duration, which may affect generalizability and align with broader research calling for larger, longer studies (Idha Isnaningrum & Novi Marliani, 2025). The short duration also limits the ability to observe sustained improvement and long-term skill retention in children (Salma et al., 2023). Nevertheless, the results provide preliminary evidence supporting the effectiveness of culturally integrated STEAM-PJBL modules for enhancing fine motor skills and engagement (Ngili, 2024). Thus, while effective, the findings should be interpreted with caution and contextual considerations in mind.

Future research should examine long-term impacts on child development including social-emotional outcomes, problem-solving abilities, and creativity and assess the adaptability of culturally integrated STEAM-PJBL modules across diverse educational contexts (Prahartiwi et al., 2025). Studies involving larger and more diverse populations can provide stronger evidence regarding the scalability and generalizability of the intervention, as evaluations of STEAM implementation across multiple early childhood settings show considerable variation in outcomes (Sativa et al., 2024). Teacher training and the development of pedagogical competence through STEAM-based instructional programs have been shown to improve teachers' ability to design and deliver effective learning experiences (Fatwakiningsih & Ismaeil, 2025). The role of early childhood teachers in applying STEAM methods reveals that teachers' skills in adapting STEAM principles and creative strategies directly influence children's engagement and learning outcomes (Hanifah & Kurniati, 2024). Mentoring teachers in designing STEAM-based learning materials also demonstrates that enhancing teacher skills can overcome implementation barriers (Hanifah & Kurniati, 2024). Moreover, specific training on developing STEAM instructional tools has been found to increase teachers' planning competence and readiness for innovative learning implementation (Priantari et al., 2022). Therefore, research and training across contexts that integrate teacher factors, learning materials, and classroom management strategies are essential to optimize STEAM implementation in early childhood education. Overall, these future directions emphasize the need to validate and expand the intervention to ensure that STEAM-PJBL learning effectively supports comprehensive and contextually relevant early childhood development.

In conclusion, this study provides evidence that integrating local culture into STEAM-PJBL learning enhances fine motor skills, child engagement, and culturally responsive learning in early childhood education. By critically analyzing the mechanisms of improvement, acknowledging practical constraints, and triangulating multiple data sources, this discussion offers a deeper understanding of why the module is effective. The findings also have practical implications for policy makers and curriculum designers, encouraging the development of learning materials that integrate local cultural elements with STEAM-PJBL principles to improve skills, engagement, and cultural awareness among children, and serving as a reference for early childhood curriculum development across diverse cultural contexts.

CONCLUSION

The implementation of local culture-based STEAM-PJBL successfully achieved the research objective of enhancing fine motor skills in early childhood. Classroom trials demonstrated a clear quantitative improvement, increasing from 67% to 80.75%. This module aligns with constructivist and socio-cultural learning theories, showing that culturally grounded hands-on activities—such as Batik Besurek patterns, clay modeling, and simple bamboo constructions—effectively strengthen children's engagement, creativity, and problem-solving abilities. These findings provide practical implications for teachers and curriculum developers to design culturally responsive, interactive learning experiences that support fine motor development. However, limitations include the small sample size and short implementation period. Future research should investigate long-term effects, explore broader developmental domains, and evaluate the adaptability of this approach across diverse cultural settings.

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