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STEAM Project-Based Science Learning Design as a Strategy to Improve Digital Literacy and Student Motivation

Nur Lena[1,2*], Muhammad Syaipul Hayat[1], Mega Novita[1]
[1]Universitas PGRI Semarang, Jawa Tengah, Indonesia
[2]*Sekolah Menengah Pertama* (SMP) Negeri 2 Tirto Pekalongan, Indonesia
Nurlena492@gmail.com*

Abstract

This research is motivated by the importance of STEAM-based learning in enhancing students' digital literacy and learning motivation within junior high school science education. The study aims to describe the characteristics and analyze the validity, practicality, and effectiveness of STEAM-based learning materials covering the topics of temperature, heat, and thermal expansion. Employing both quantitative and qualitative approaches, this Research and Development (R&D) study utilizes the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The research subjects included subject matter experts, media experts, science teachers, and 7th-grade students from SMP Negeri 2 Tirto. Data were collected using validation instruments, response questionnaires, implementation observations, digital literacy tests (pre-test and post-test), and learning motivation questionnaires. The data were tested for validity, reliability, normality, and homogeneity, and subsequently analyzed using descriptive qualitative methods and parametric statistics (paired sample t-test, independent sample t-test, and N-gain). The results indicate that the developed STEAM learning materials comprising teaching modules, instructional materials, and student worksheets (LKM) incorporate STEAM indicators and digital media. The materials proved highly valid, with average validity scores of 85% for teaching modules, 84% for instructional materials, and 87% for student worksheets. Practicality ratings were also very high based on teacher and student feedback: 95% for teaching modules, 92% for instructional materials, and 89% for student worksheets. Implementation of these materials effectively strengthened students' digital literacy specifically regarding critical information searching, digital collaboration, and internet ethics while simultaneously boosting learning motivation, including perseverance, tenacity, and self-confidence. In conclusion, STEAM-based learning enhances the quality of science instruction, digital literacy, and student learning motivation through an active, meaningful, and collaborative process.

Keywords: Learning Materials, STEAM, Temperature Heat and Thermal Expansion, Digital Literacy, Learning Motivation

INTRODUCTION

Transforming science education at the secondary school level presents significant challenges amidst the rapid technological advancements of the digital era (Subroto et al., 2023). Modern science instruction is expected not only to deliver conventional content but also to foster digital literacy and stimulate student learning motivation (R. K. Sari et al., 2021; Sukmawati & Rakhmawati, 2023). However, evidence from the field indicates that the utilization of digital technology and interdisciplinary approaches in science education

remains suboptimal (D. T. Kurniawan & Abidin, 2024; Rabia et al., 2024). Reliance on single teaching methods without integrating interactive digital media tends to render students passive; this manifests as weak digital literacy particularly regarding the retrieval of credible information, scientific data management, and digital collaboration (Kurt & Dindar, 2025; Sudartinah & Hadi, 2023). Furthermore, a learning environment disconnected from real-life realities contributes to declining learning motivation, reflected in students' low enthusiasm and lack of persistence when completing science assignments (Fu'adi et al., 2022; Marlangen et al., 2023).

The root of the problem lies in the limited availability of contextual learning designs capable of cohesively integrating science with technology, engineering, arts, and mathematics (Afandi et al., 2024; Bybee et al., 2021). Consequently, students struggle to grasp the practical implications of scientific concepts in real-life contexts (Roshayanti et al., 2022; Sutoyo et al., 2023; Wijayanti et al., 2021). Various prior studies have sought to address this issue through innovations in learning models and media. (Gani et al., 2025) indicates that a digital media-oriented Project-Based Learning (PjBL) framework effectively enhances student participation. Meanwhile, (Sukmawati & Rakhmawati, 2023) emphasize that the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach is potent in fostering creativity and problem-solving skills. Additionally, (Jasmaniah et al., 2025) demonstrates that the use of digital collaboration tools can boost student motivation to learn science topics a finding reinforced by (A. A. Kurniawan et al., 2024) regarding the effectiveness of interactive platforms.

Although various studies have demonstrated the effectiveness of PjBL, STEAM, and technology in isolation, a research gap remains regarding how to formulate a STEAM Project-Based Learning (STEAM-PjBL) science instructional design that systematically boosts both digital literacy and student learning motivation simultaneously (Kalyoncu et al., 2023; Liu et al., 2024). Most literature focuses primarily on cognitive learning outcomes (Fitriani et al., 2024; A. F. A. Sari, 2025) without deeply evaluating the development of students' motivation and digital skills during project completion (Balaya et al., 2024; Sälevä, 2025).

Given this urgency, this study was conducted to design, validate, and measure the effectiveness of a STEAM-PjBL-based science learning design as a solution for enhancing students' digital literacy and learning motivation (Febiola, n.d.; M Nazali Romadhon, 2025). The study's novelty lies in the systematic integration of STEAM projects with interactive digital platforms across every learning phase, thereby creating a learning experience that is holistic, contextual, and adaptive to 21st-century needs (Vraga et al., 2021).

METHOD

This study employed an Educational Research and Development (R&D) framework utilizing the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. To empirically evaluate the instructional efficacy of the developed product, the implementation phase integrated a quasi-experimental pretest-posttest control group design (Sugiono, 2013). The research was conducted at SMP Negeri 2 Tirto, Pekalongan Regency, Indonesia, during the even semester of the 2025/2026 academic year. Participants were divided into two main groups: an expert validation panel comprising subject matter experts, instructional media specialists, and science education practitioners responsible for assessing construct and content validity, and Grade VII students divided into an experimental class receiving the STEAM-PjBL intervention and a control class undergoing conventional instruction.

The experimental intervention followed a structured five-phase STEAM-PjBL instructional cycle. First, problem identification contextualized socio-scientific issues surrounding temperature, heat, and thermal expansion. Second, project design allowed students to formulate interdisciplinary STEAM solutions and

establish project workflows. Third, scheduling and project execution involved creating digital artifacts using interactive software under teacher guidance. Fourth, monitoring and evaluation enabled testing and refining the digital artifacts based on continuous formative assessment. Finally, publication and reflection concluded the cycle through product presentations and metacognitive evaluations of the learning process.

Data collection was executed using a comprehensive multi-method assessment strategy. Material validity and user practicality were evaluated using structured expert rating scales and Likert-based response questionnaires. Student digital literacy levels were measured via pre- and post-intervention cognitive tests, while learning motivation was assessed through Likert-scale questionnaires triangulated with observational rubrics during project execution. Qualitative validation feedback was converted into percentage scores to determine validity and practicality thresholds. For performance metrics, statistical prerequisites specifically tests for normality and homogeneity of variance were satisfied prior to computing individual gains using the Normalized Gain (N-gain) formula. Finally, a Multivariate Analysis of Variance (MANOVA) was conducted at a significance level of $\alpha = .05$ to evaluate the simultaneous main effect of the STEAM-PjBL intervention on student digital literacy and learning motivation.

RESULTS AND DISCUSSION

The development of the STEAM Project-Based Learning (STEAM-PjBL)-based science learning design began with a validation process conducted by a team of experts, comprising subject matter experts, media experts, and practitioners (science teachers). Qualitative and quantitative assessment results from the validators served as the basis for evaluating the product's feasibility prior to its implementation in the experimental class. A summary of the expert validation results is presented in Table 1.

Table 1. Feasibility Validation Results for the STEAM-PjBL Learning Design

Assessment Aspect	Average Score (%)	Feasibility Category
teaching materials	92%	Highly Feasible
teaching modules	95%	Highly Feasible
student worksheets	89%	Feasible
Overall Average	92%	**Highly Feasible**

Based on Table 1, the STEAM-PjBL-based science learning design achieved an average validity score of 92%, falling into the "highly feasible" category. Suggestions for improvement from the validators included adjusting the time allocation for the "Application & Creation" phase and simplifying the digital platform interface used by students. Following revisions, the learning design was pilot-tested and received a practicality rating of 92% from students, indicating that the learning materials and instructional flow were practical and effective for science learning.

The impact of implementing the STEAM-PjBL design on students' digital literacy was measured by comparing pretest and posttest scores between the experimental class (STEAM-PjBL instruction) and the control class (conventional instruction). The results of the descriptive analysis and N-gain test regarding digital literacy are summarized in Table 2.

Table 2. Improvement in Students' Digital Literacy Skills

Group	Mean Pretest	Mean Posttest	Mean N-gain	N-gain Category
Experimental Class	60,59	77,28	0,53	Moderate
Control Class	57,00	60,00	0,28	Low

The improvement in digital literacy in the experimental class fell into the moderate category (N-gain = 0.53), whereas the control class fell into the low category (N-gain = 0.28). The notable improvement observed in the experimental class was particularly evident in the indicators of digital collaboration and information seeking. This is attributed to the students' gradual engagement with interactive digital media during the execution of STEAM projects.

These findings align with research by (Mahartika et al., 2024), which states that integrating digital platforms into science projects trains students to filter and manage scientific information continuously. Students' direct involvement in operating digital tools while designing group projects helps foster a habit of interacting with technology in a more purposeful manner (Yulia, 2024).

Data on student learning motivation were obtained via a Likert-scale questionnaire administered before and after the intervention. Analysis results indicate that the class implementing the STEAM-PjBL design experienced a measurable increase in learning motivation compared to the control class, as shown in Table 3.

Table 3. Analysis Results of Student Learning Motivation

Group	Initial Score	Final Score	Percentage Increase	Category
Experimental Class	30,00	80,00	26,66%	High
Control Class	20,00	30,00	15,00%	Moderate

The increase in learning motivation in the experimental class was driven by students' enthusiasm for completing the project cycle. During the Research & Discovery and Application & Creation phases, students demonstrated significant perseverance in designing STEAM-based products. The presentation of contextual problems made science learning feel more relevant to the students' daily activities.

Theoretically, these results support the findings of (Gani et al., 2025), who argued that a Project-Based Learning approach integrated with Arts and technology elements (STEAM) can create a more interactive learning environment and foster students' drive for independent learning. Active student involvement in project exhibitions or presentations (Connection) also provided a positive experience that bolstered their confidence regarding the science (IPA) subject matter.

To test the research hypothesis regarding the simultaneous effect of implementing the STEAM-PjBL design on students' digital literacy and learning motivation, a Multivariate Analysis of Variance (MANOVA) test was conducted. Prior to the MANOVA test, the data were confirmed to meet the analysis prerequisites: normal distribution ($p > 0.05$) and homogeneity ($p > 0.05$). The MANOVA test results are presented in Table 4.

Table 4. MANOVA Test Results (Pillai's Trace & Wilks' Lambda)

Effect Test	Statistic Value	F-value	Sig. (p-value)	Conclusion
Pillai's Trace	0,382	18,450	0,000	Significant ($p < 0,05$).
Wilks' Lambda	0,618	18,450	0,000	Significant ($p < 0,05$).

Based on Table 4, the significance value obtained from the Wilks' Lambda test is 0.000 ($p < 0.05$). This indicates that the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. Thus, there is a significant simultaneous effect of implementing the STEAM-PjBL-based science learning design on improving the digital literacy and learning motivation of junior high school students.

The synergy between the STEAM approach and the PjBL synthesis has proven to contribute positively to the learning ecosystem. When students are faced with interdisciplinary projects that require

solving scientific problems through simple technological engineering and artistic creativity, they are encouraged to explore digital tools (digital literacy) while simultaneously developing a sense of attachment to the work they produce (learning motivation). Consequently, science learning becomes more varied and contextual.

CONCLUSION

This study demonstrates that the Project-Based Learning (PjBL) instructional materials integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) alongside digital literacy for topics on temperature, heat, and thermal expansion are highly valid, practical, and effective. Content validation and practicality evaluations across teaching modules (85%), instructional materials (84%), and student worksheets (87%) confirm that the design is structurally sound and implementation-ready without requiring major revisions. Furthermore, inferential statistical tests (t-test) and N-gain analyses revealed a statistically significant enhancement in both digital literacy and learning motivation among experimental group students compared to those in the traditional control group.

These findings underscore the potential of digital STEAM-PjBL frameworks in modernizing secondary science education. Practically, science educators are encouraged to implement this model incrementally by establishing realistic project schedules and adopting user-friendly digital tools. To sustain this pedagogical transition, school administrators must provide stable information technology infrastructure. Finally, future research should expand upon these results by testing the instructional framework across larger, more diverse student cohorts while evaluating its long-term impact on broader higher-order thinking skills, such as critical thinking and analytical reasoning.

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