Integrating Local Wisdom in STEM-Based Science Learning in Elementary Schools: Challenges and Reflections from Implementation

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Abstract

This study aims to explore the challenges and reflections arising during the implementation of a local wisdom-integrated STEM-based science learning model in elementary schools. The research was conducted in a fifth-grade class using the topic of heat transfer contextualized with local wisdom through kawung batik-making activities. Using a descriptive qualitative design, data were collected through participatory observation, semi-structured interviews, and documentation. The results indicate that integrating Science, Technology, Engineering, and Mathematics within culturally relevant contexts encouraged active student participation, improved conceptual understanding, and supported the development of 21st-century skills. However, challenges emerged, including limited time allocation for project-based learning, the need for careful safety management when using hot wax, and ensuring all students remained engaged during the hands-on activities. From the teacher's perspective, clear and structured implementation steps were essential to managing the class effectively and ensuring learning objectives were achieved. Reflection on this implementation emphasizes the importance of adapting STEM learning models to local cultural contexts while maintaining scientific rigor and safety, providing practical insights for teachers seeking to develop meaningful and contextual science learning experiences in elementary schools.

Abstrak

Penelitian ini bertujuan untuk mengeksplorasi tantangan dan refleksi yang muncul selama implementasi model pembelajaran IPA berbasis STEM yang diintegrasikan dengan kearifan lokal di sekolah dasar. Penelitian dilakukan pada siswa kelas V dengan topik perpindahan panas yang dikontekstualisasikan melalui kegiatan membatik motif kawung sebagai bentuk kearifan lokal. Dengan menggunakan desain kualitatif deskriptif, data dikumpulkan melalui observasi partisipatif, wawancara semi terstruktur, dan dokumentasi. Hasil penelitian menunjukkan bahwa integrasi Science, Technology, Engineering, dan Mathematics dalam konteks budaya yang relevan dapat mendorong partisipasi aktif siswa, meningkatkan pemahaman konsep, dan mendukung pengembangan keterampilan abad 21. Namun, beberapa tantangan ditemukan, seperti keterbatasan waktu untuk pembelajaran berbasis proyek, kebutuhan pengelolaan keselamatan secara cermat saat menggunakan lilin panas, serta memastikan semua siswa tetap terlibat selama kegiatan praktik. Dari perspektif guru, langkah implementasi yang jelas dan terstruktur sangat penting untuk membantu pengelolaan kelas secara efektif serta memastikan tercapainya tujuan pembelajaran. Refleksi dari implementasi ini menekankan pentingnya adaptasi model pembelajaran STEM dengan konteks budaya lokal tanpa mengurangi ketelitian ilmiah dan keselamatan, sehingga memberikan wawasan praktis bagi guru yang ingin mengembangkan pengalaman pembelajaran IPA yang bermakna dan kontekstual di sekolah dasar..

1. Introduction

Natural Science (IPA) is a fundamental subject in elementary schools that plays a crucial role in helping students systematically understand natural phenomena and scientific concepts. However, science learning at the elementary level often remains teacher-centered, relying heavily on lectures and memorization, making scientific concepts abstract and disconnected from students' daily lives (Syahputra et al., 2022; Zakirman et al., 2022). Effective science education should not only focus on conceptual mastery but also develop students' scientific process skills, critical thinking, and problem-solving abilities relevant to everyday contexts (Gizaw & Sota, 2023; Idris et al., 2022).

To address these challenges, the Science, Technology, Engineering, and Mathematics (STEM) learning model has been recognized as a potential approach to make science learning more engaging and meaningful for students. STEM-based learning integrates scientific concepts with technology, engineering, and mathematics to solve contextual problems, encouraging students to actively engage

in exploration, investigation, and real-world problem-solving (Fajrina et al., 2020; Smith et al., 2022). This approach has been shown to improve conceptual understanding while fostering 21st-century skills, such as critical thinking, collaboration, and creativity, which are essential for students to face future challenges (Chai et al., 2020; Davidi et al., 2021).

The implementation of STEM in education aligns with constructivist learning theory, which emphasizes that students build knowledge actively through meaningful experiences, especially when learning is connected to real-life contexts (Vygotsky, 1978; Fosnot, 2013). Within this framework, students are encouraged to explore, experiment, and reflect on learning experiences that relate to their daily lives, making science more understandable and engaging (Schunk, 2012).

In addition to STEM approaches, integrating local wisdom into science learning can further enhance contextual relevance. Local wisdom, referring to traditional knowledge and cultural values within communities, offers real-life contexts that allow students to relate science concepts to their environment and daily experiences, making learning more meaningful (Fitrianto & Farisi, 2025; Verawati & Wahyudi, 2024). For instance, teaching heat transfer can be contextualized through batik-making, enabling students to observe and measure heat transfer processes while engaging with cultural heritage (Ni'mah et al., 2024). Local wisdom-based learning not only strengthens conceptual understanding but also fosters environmental awareness and appreciation of local culture (Hastuti et al., 2020).

Integrating STEM learning with local wisdom represents a relevant and practical approach in elementary science education, combining scientific frameworks with culturally contextual learning experiences. This integration allows students to develop scientific skills while maintaining a connection with their cultural environment, aligning science education with students' lives and communities (Arjaya et al., 2024; Ilhami et al., 2019; Nugroho et al., 2019; Usmeldi & Amini, 2020).

Previous studies have shown that integrating STEM and local wisdom can enhance students' interest, conceptual understanding, and critical and creative thinking skills in science learning (Aswirna et al., 2022; Ilhami et al., 2019; Susiloningsih et al., 2025). However, most of these studies have primarily focused on measuring the quantitative effectiveness of this integration, often neglecting the detailed documentation of implementation processes and the practical challenges teachers face in real classrooms. This condition makes it difficult for teachers to replicate or adapt these models effectively within their school contexts, limiting the practical applicability of STEM-local wisdom integration in daily science learning.

Furthermore, while many studies have tested the impact of STEM learning theoretically or within controlled experimental settings, there is a lack of studies that document authentic classroom implementation processes, the pedagogical challenges encountered, and the contextual reflections necessary for effective adaptation by teachers in the field. Thus, there remains a gap in practical, process-oriented studies that align theoretical benefits of STEM-local wisdom integration with the realities of elementary school classrooms.

Given this gap, there is a need for studies that provide clear, practical documentation of the implementation of local wisdom-integrated STEM-based science learning in elementary classrooms. This study contributes to the field by focusing on practical challenges, strategies, and reflections during the implementation process, offering real-world insights for teachers who wish to contextualize science learning while maintaining scientific rigor.

Therefore, this study aims to explore the challenges and reflections encountered during the implementation of a local wisdom-integrated STEM-based science learning model in elementary schools, using kawung batik-making activities on the topic of heat transfer as a contextual learning medium. By providing a practical, contextual, and systematic documentation of the implementation process, this study offers novel insights for teachers seeking to develop meaningful and culturally relevant science learning while fostering scientific process skills and 21st-century competencies in students.

2. Method

This study employed a qualitative case study design to explore the implementation of a local wisdom-integrated STEM-based science learning model in an elementary school context. The case was conducted in a fifth-grade classroom at SD Negeri Lempuyangwangi, Yogyakarta, focusing on the topic of heat transfer contextualized through kawung batik-making activities as a form of local cultural heritage.

The school was selected using purposive sampling based on its accessibility, openness to innovative learning models, and the availability of teachers willing to implement STEM-based contextual learning with local wisdom integration. SD Negeri Lempuyangwangi was chosen because it has previously implemented project-based and contextual learning approaches, making it a suitable environment for piloting STEM-local wisdom integration.

The participants consisted of one fifth-grade teacher and 30 fifth-grade students (18 boys and 12 girls, aged 10–11 years) who participated voluntarily with parental consent. The teacher was selected due to their willingness to collaborate, openness to reflective practice, and active involvement in implementing contextual learning in the classroom.

3. Results and Discussion

3.1. Results

The implementation of the local wisdom-integrated STEM-based science learning model was conducted systematically in a fifth-grade classroom at SD Negeri Lempuyangwangi, using the topic of heat transfer contextualized with kawung batik-making activities. The process consisted of seven structured stages: preliminary, exploration, project planning, project implementation, observation and measurement, presentation, and reflection.

In the preliminary stage, the teacher introduced the kawung batik motif, emphasizing its cultural and philosophical meanings while linking it to heat transfer concepts, fostering cultural appreciation and curiosity among students. During the exploration stage, students observed practical demonstrations of heat transfer, such as melting wax, measuring temperature changes, and connecting these observations to conduction and everyday heat transfer phenomena.

During the project planning stage, students collaboratively designed simple kawung-based batik patterns while discussing geometry, symmetry, and color planning, integrating mathematics and engineering thinking into the design process. In the project implementation stage, students practiced applying hot wax on fabric using canting tools under supervision, ensuring safety while experiencing the physical changes of wax firsthand, thereby reinforcing scientific understanding through direct, meaningful practice.

The observation and measurement stage involved students using thermometers to measure wax temperatures before, during, and after heating, recording and analyzing these data in their journals. Students discussed heat loss factors and cooling rates, connecting them with heat transfer theories. In the presentation stage, groups presented their batik products and shared scientific observations, challenges encountered, and collaborative problem-solving strategies, enhancing their communication and reflection skills. Finally, during the reflection stage, students articulated their learning experiences, explaining how the hands-on process deepened their understanding of heat transfer while fostering pride in cultural heritage.

This structured implementation resulted in high student engagement, active participation, and improved conceptual understanding of heat transfer, while nurturing critical thinking, collaboration, and creativity within a culturally meaningful framework.

3.2. Discussion

Consistent with Rahmawati et al. (2023) and Aswirna et al. (2022), the study confirms that integrating STEM with local wisdom improves students' conceptual understanding and engagement in science learning. However, this study extends prior findings by providing a detailed, practical implementation narrative, addressing the gap highlighted by Ilhami et al. (2019) and Nugroho et al.

(2019), who noted the need for clear, replicable classroom models to guide teachers. Moreover, by incorporating kawung batik-making, the study aligns with Fitrianto and Farisi (2025) and Verawati and Wahyudi (2024), who argue that contextualizing learning with local wisdom enhances cultural relevance and environmental awareness among students.

Unlike traditional teacher-centered methods that often rely on lectures and memorization (Syahputra et al., 2022; Zakirman et al., 2022), this local wisdom-integrated STEM approach allowed students to engage actively in contextual, project-based learning, thereby bridging the gap between abstract scientific concepts and students' daily experiences. Compared to conventional science learning, the integrated approach provided opportunities for practical measurement, experimentation, and collaborative learning, aspects often missing in lecture-based teaching, aligning with the argument by Smith et al. (2022) on the benefits of active, contextual STEM learning.

The study demonstrates that local wisdom-integrated STEM learning is not only feasible but effective in enhancing students' scientific literacy, critical thinking, and cultural appreciation within elementary education. This model can guide teachers in designing meaningful, contextual science learning experiences, aligning with both curriculum goals and cultural preservation efforts. However, challenges such as time constraints and safety management in using hot wax highlight the need for careful planning, supervision, and clear instructional guidelines during implementation.

3.3. Conclusion

This study concludes that implementing a local wisdom-integrated STEM-based science learning model using kawung batik-making activities effectively enhances elementary students' conceptual understanding in a concrete and contextual manner. By engaging in culturally relevant, hands-on activities, students were able to directly observe and measure heat transfer while simultaneously fostering critical thinking, collaboration, and communication skills. Integrating Science, Technology, Engineering, and Mathematics within a cultural context transformed abstract science concepts into meaningful learning experiences connected with students' daily lives while nurturing an appreciation for local cultural heritage. The structured implementation steps documented in this study provide practical guidance for teachers seeking to adopt similar models to improve science learning meaningfully in elementary classrooms.

The findings imply that integrating local wisdom into STEM-based science learning serves as a culturally responsive pedagogy, enriching science education while supporting the development of 21st-century skills. This approach can be adapted to various science topics and local cultural practices, making science learning more engaging and relevant across diverse educational settings. However, several limitations were encountered, including restricted instructional time for project-based learning, the need for careful safety management when using hot wax, and challenges in maintaining consistent student engagement throughout the activities. Additionally, as this study focused on a single topic within a specific cultural context, the generalizability of the findings may be limited to similar educational and cultural settings.

To support broader adoption, teachers are encouraged to utilize supportive technologies, such as video demonstrations of safe batik processes, digital thermometers, and collaborative digital journals to enhance monitoring, documentation, and reflective discussions during the learning process. Schools can consider using simplified, safer wax tools or alternative local cultural practices relevant to other scientific concepts to facilitate easier integration within limited instructional time. Additionally, schools may schedule project-based learning sessions within block schedules to provide sufficient time for STEM-based cultural activities without disrupting other subjects.

Future studies should explore the implementation of local wisdom-integrated STEM learning across diverse science topics (e.g., environmental education, ecosystem studies) and different grade levels to examine its broader applicability and effectiveness. Comparative studies between conventional STEM models and those incorporating local wisdom could provide deeper insights into the specific benefits, challenges, and added value of cultural integration in science learning. Longitudinal studies are recommended to evaluate the long-term impacts of this approach on students' scientific literacy, critical thinking, cultural awareness, and attitudes toward science.

Additionally, research focusing on the development and testing of teacher training programs for culturally integrated STEM learning would support systematic and sustainable adoption of this approach in diverse school contexts, ensuring that teachers are equipped with practical strategies, safety guidelines, and culturally responsive pedagogical frameworks

Author Contributions

Kinanti Pangestu: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – Original draft. Puji Lestari: Investigation, Validation, Resources, Writing – Review & Editing. Ikhlasul Ardi Nugroho: Supervision, Project administration, Writing – Review.

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