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Analysis of Teachers' Constraints and Strategies in Designing STEM-Based Learning: A Case Study at Muhammadiyah 1 Candi Elementary School, Labschool UMSIDA

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ABSTRACT

Objective: *This research aims to explore the constraints and strategies of teachers in designing STEM-based learning (Science, Technology, Engineering, and Mathematics) in elementary schools.* ***Method:*** *Using a qualitative case study approach, data were collected through in-depth interviews with the curriculum coordinator and upper-grade teachers (IV, V, and VI), as well as documentation analysis of teaching module drafts.* ***Results:*** *The results revealed a strong synchronization between teachers' conceptual understanding of STEM as a driver of "deep learning" and practical implementation in learning tools. Nevertheless, this study identified systemic barriers in the form of limited curriculum time allocation, challenges in developing objective performance assessments, and technological facility constraints. To address these issues, teachers implemented adaptive strategies through the use of local materials (low-cost STEM), routine collaboration in internal Teacher Working Groups (KKG), and digital literacy based on project modification. Overall, the consistency between perception and instructional practice indicates teacher readiness in integrating STEM, but strengthening assessment rubrics and school schedule flexibility is required to optimize learning outcomes.* ***Novelty:*** *The primary design strategies found were the mapping of Learning Outcomes (CP) and the use of a simplified Engineering Design Process (EDP) framework.*

INTRODUCTION

Education in the global era demands mastery of 21st-century skills that include critical thinking, creativity, collaboration, and communication as the main foundation for students. *The Science, Technology, Engineering, and Mathematics* (STEM) approach has emerged as a strategic solution to integrate various disciplines to systematically solve real-life problems [1]. In Indonesia, the implementation of STEM has begun to be strengthened in line with the direction of the national curriculum policy that emphasizes meaningful and contextual learning [2]. However, the success of this approach at the elementary school level depends heavily on the readiness of teachers as the main instructional designers in the classroom [3]. Without careful planning, the great potential of STEM education will not be optimally conveyed to students [4].

The reality on the ground shows that the adoption of STEM in elementary schools still faces a gap between policy demands and implementation capabilities. Many teachers agree on the importance of this innovation, but they often feel unsure about integrating engineering elements *into* science materials [3]. Limited conceptual understanding results in STEM learning often being viewed as merely a craft activity without in-depth scientific analysis [5]. In addition, the transition to a new curriculum requires teachers to have high flexibility in developing complex teaching modules [6]. Therefore, an in-depth analysis of the obstacles experienced by teachers in the planning phase is crucial [7].

The main obstacle that often arises is the difficulty teachers have in distinguishing between conventional learning and an integrated STEM approach. Research shows that the majority of elementary school teachers are still trapped in teaching subjects separately or in silos, so that the meaning of integration is lost [3]. The Engineering Design Process (EDP) is often overlooked in planning documents prepared by teachers [5]. This is exacerbated by the low literacy of teachers regarding aspects of technology that should be a supporting tool, not just a visual medium [8]. As a result, the resulting learning modules tend to be repetitive and less challenging to students' critical reasoning [9].

In addition to conceptual barriers, technical aspects related to the use of information technology-based media are also a real challenge. Teachers often experience difficulties in selecting and integrating digital devices that are appropriate to the characteristics of STEM material in elementary schools [8]. Limited time to experiment with new media makes teachers tend to return to safer but less innovative lecture methods [10]. Mastery of *Higher Order Thinking Skills (HOTS)* -based learning evaluation is also still a weak point that hinders the quality of learning designs [8]. In fact, appropriate assessment is very necessary to measure the achievement of process skills in students.

The institutional environment and school culture also play a determining role in facilitating curriculum innovation for teachers. As a laboratory school, SD Muhammadiyah 1 Candi Labschool Umsida has a mandate to become a center for developing superior pedagogy [11]. However, the administrative burden and high expectations for teacher performance often take up time that should be used to collaborate in designing STEM modules [6]. The availability of laboratory facilities and policy support from school management greatly influence the level of teacher creativity in innovation [2]. Without a supportive ecosystem, teacher initiatives to implement project-based learning will be difficult to sustain in the long term [12].

Faced with these various obstacles, teachers usually develop specific coping strategies to continue learning. Collaboration through internal Teacher Working Groups (KKG) is one way to share knowledge and resources in developing modules [13]. Some teachers have also begun utilizing digital platforms to find references for teaching materials that have been practically tested [12]. Mentoring from universities as *labschool supervisors* is also expected to be able to bridge the competency gap experienced by educators [6]. Mapping these strategies is crucial for finding patterns of success that can be replicated by other schools [14].

Based on the context of the problems described, the research problem formulation in this study focuses on three main points. First, what are the conceptual and technical difficulties faced by high school teachers in designing a STEM-based curriculum? Second, how do environmental and institutional factors contribute to the obstacles experienced by teachers during the planning process? Third, what strategies do teachers implement to overcome these obstacles in their curriculum design practices? These questions are designed to uncover hidden challenges within the instructional development process.

Each question will be answered through a qualitative case study approach conducted in depth and systematically.

The main objective of this study is to comprehensively identify and describe the obstacles faced by teachers at Muhammadiyah 1 Candi Labschool Umsida Elementary School. Specifically, this study aims to map the gaps in understanding and technical obstacles in developing STEM learning modules experienced by high school teachers. In addition, this study aims to analyze the extent to which school culture and the availability of facilities influence teacher creativity in creating learning innovations. Another objective is to provide strategic recommendations for school management in supporting teachers during the national curriculum transformation process. By achieving these objectives, this study is expected to make a real contribution to the development of inclusive STEM education in Indonesia [14].

This research is expected to provide a dual contribution, both theoretically and practically, to the world of elementary education. Theoretically, the results of this study will enrich the literature on STEM curriculum design management in the context of laboratory schools in developing countries. Practically, these findings can be used as evaluation material for school principals to adjust professional support policies for teachers. Educators can also use the results of this study as a collective reflection to improve the quality of the teaching materials they develop. Finally, for fostering institutions such as Umsida, this data can serve as a reference in designing more targeted and sustainable teacher training programs [13].

Designing STEM-based learning is a critical stage that determines the quality of education in the future. Although elementary school teachers face multidimensional challenges, ranging from cognitive to managerial aspects, efforts to continue to innovate must not stop. An analysis of the obstacles and strategies implemented by teachers at SD Muhammadiyah 1 Candi Labschool Umsida will provide a concrete picture of the dynamics of curriculum transformation in the field. Successfully overcoming these design obstacles is a crucial first step in producing a generation that is scientifically and technologically literate. Therefore, this research is highly relevant to implement to promote a more progressive and competitive quality of learning.

RESEARCH METHOD

This study uses a qualitative approach with a case study design to explore in depth the phenomenon of teacher obstacles in designing STEM learning. The use of descriptive qualitative methods is considered appropriate because researchers seek to understand the complex reality behind the curriculum planning process carried out by educators [3] . Through case studies, researchers can capture the unique challenges faced by high-grade teachers in a laboratory school environment [15]. This design allows for the collection of rich and in-depth data regarding teachers' perceptions, obstacles, and coping strategies in integrating elements of science and technology [1]. The main focus of this procedure is to provide a systematic overview of the "gap" between STEM theory and design practices in the field [5].

Location and Time of Research This research was conducted at Muhammadiyah 1 Candi Elementary School, which has the status of *Labschool* of Muhammadiyah University of Sidoarjo (UMSIDA). This location was chosen purposively considering the school's position as a center of innovation and a pilot project for STEM-based curriculum development in the Sidoarjo region [11] . Its status as a laboratory school provides a unique context because teachers are expected to have higher design competency standards than those in public schools [9] . The research was scheduled to last for one semester to cover the planning phase, module development, and evaluation of teaching materials [6] . The collaborative school environment provides an ideal setting to observe the interaction between institutional policies and individual teacher creativity [2] .

Research Subjects The main subjects in this study were high school teachers (grades IV, V, and VI) who were responsible for implementing STEM-integrated science subjects. The selection of high school teachers was based on the complexity of the science material at that level, which requires stronger integration of engineering and mathematics *elements* [1] . Informants were selected using *purposive sampling techniques* to ensure that data were obtained from practitioners who were actually developing STEM modules. In addition to teachers, the researcher also involved the Vice Principal for Curriculum as a supporting informant to strengthen data regarding school policy support [11] . The diversity of teaching experiences of these teachers is expected to provide a broad perspective on the technical obstacles experienced [12] .

The primary data collection technique was conducted through semi-structured *in-depth interviews. The interviews focused on exploring teachers' conceptual understanding, obstacles in developing the Engineering Design Process* (EDP) steps, and challenges in determining appropriate assessments [5] . Researchers prepared interview guidelines to keep the discussion focused while still providing space for teachers to share their subjective experiences [3] . The interviews were recorded and carefully transcribed to maintain the authenticity of informants' statements regarding their strategies for overcoming idea blockages [7] . Through this dialogue, researchers were able to identify the reasons behind teachers' low self-confidence in integrating technology into teaching materials [8] .

In addition to interviews, researchers conducted document analysis of the STEM-based Teaching Modules or RPPs that had been prepared by teachers. The documents were dissected to see the extent to which elements of interdisciplinary integration and environmental literacy components had emerged in real terms [10] . This document analysis aimed to verify whether the teachers' statements in the interviews were in line with the resulting learning device products [5] . Researchers used a document review sheet that included indicators of subject integration and the suitability of HOTS-based assessment instruments [8] . Gaps found between the planning documents and the ideal STEM standards will be recorded as significant research findings [4] .

Limited participant observation was conducted to observe how the designs were implemented or discussed in internal teacher forums. Observations focused on the collaborative process of teachers within the Teacher Working Group (KKG) as they attempted to resolve the issue of availability of project tools and materials [13] . The researcher acted as an observer, recording the dynamics of the discussions and any technical constraints that arose spontaneously during the preparation phase [10] . These observational data served as support to strengthen the findings from the interviews regarding the influence of school facilities on design creativity. Field notes were systematically compiled to capture the atmosphere of innovation in the laboratory school [15] .

The main instrument in this study was the researcher himself (*human instrument*) supported by interview guidelines and observation sheets. The interview guidelines were developed based on the dimensions of STEM challenges that include cognitive, technical, and institutional aspects [14] . The document analysis sheet was designed by referring to the 4C skills performance assessment rubric criteria relevant to 21st-century learning [16] [8] . Before being used, all instruments went through an expert *judgment validation process* to ensure the measurability and relevance of the questions to the research objectives. Instrument validity is crucial so that the collected data can accurately answer the problem formulation regarding teacher strategies.

The collected data was analyzed using an interactive model from Miles and Huberman consisting of data reduction, data presentation, and drawing conclusions [2] . In the reduction stage, researchers sorted data from interview transcripts and field notes that were most relevant to STEM design constraints [17] . Next, the data was presented in the form of descriptive narratives and comparative tables between theory and facts in the field to facilitate understanding of patterns. Researchers looked for dominant themes that emerged, such as difficulties in *engineering aspects* or obstacles to teachers' digital literacy [18] . The final stage was drawing conclusions which was carried out continuously to ensure the findings were based on strong evidence [2] .

To ensure the validity and reliability of the research results, researchers applied data triangulation techniques [19] [20] . Source triangulation was carried out by comparing information from class teachers, principals, and curriculum documents to obtain a complete perspective [10] . In addition, technical triangulation was applied by checking the consistency of data between interview results, observation results, and the contents of learning device documents. Researchers also conducted *member checks* by reconfirming the analysis results with informants to avoid misinterpretation. These steps were taken so that the findings regarding teacher strategies in overcoming obstacles had a high level of academic credibility [1] .

The research procedure began with obtaining official permits from relevant institutions and coordinating with Muhammadiyah 1 Candi Elementary School. Research ethics were upheld by ensuring the confidentiality of informants' identities through the use of initials and requesting *informed consent* before data collection. The entire research process was conducted with the principles of objectivity and transparency, especially in reporting sensitive issues related to school facilities or policies [2] . The researcher ensured that the results of this study would be returned to the school in the form of practical recommendations for the development of teacher professionalism in the future. By following a systematic process, this research is expected to make a real contribution to the development of STEM education in Indonesia [14] .

RESULTS AND DISCUSSION

Results

This study explores how the STEM approach is implemented through in-depth interviews with the Head of Curriculum and teachers of grades 4, 5, and 6. In general, all informants had a positive view that STEM is a crucial cross-disciplinary integration in the Independent Curriculum. The grade 4 teacher emphasized that STEM helps students understand the connection between scientific theory and real-life applications in everyday life. Meanwhile, the Head of Curriculum explained that the school has strived to make STEM the main "vehicle" in the implementation of the Pancasila Student Profile Strengthening Project (P5). This implementation is considered a concrete step to support the government's policy on deep learning [1] .

The data shows that the primary strategy used by teachers in designing learning is mapping *Learning* Outcomes (CP). Fifth-grade teachers explained that they sought the most logical intersection of science and mathematics before determining which engineering aspects to use. For example, in the ecosystems topic, students were encouraged to calculate scale in creating a model as a form of mathematical integration. This process ensured that each discipline was not forced, but rather blended naturally within a single project. This aligns with findings that interdisciplinary integration is a key strategy in developing a STEM-based curriculum [21].

The engineering steps in the teaching modules at this school consistently adopt the *Engineering Design Process* (EDP) cycle. The 5th-grade teacher uses simplified stages for elementary school students, namely *Ask, Imagine, Plan, Create,* and *Improve.* These stages provide space for students not only to create products, but also to evaluate and improve their work. The 4th-grade teacher added that documenting each EDP stage is very important to monitor the development of students' thinking patterns. The use of this EDP has been proven to hone students' critical thinking skills and problem-solving abilities systematically [12] .

Although teachers' understanding was quite good, there were significant challenges in technical and structural aspects. Table 1 summarizes the various obstacles and coping strategies identified during field observations and interviews.

Table 1. Summary of Interview Results Regarding STEM Implementation.

No	Component	Key Findings	Adaptation Strategy
1	Understanding	STEM is considered a key driver in deep learning	Regular discussions of teacher working groups (KKG) at school
2	Design	Teachers carry out *mapping* of learning outcomes (CP) to find	Using a simplified *Engineering Design Process (EDP) framework*

		material that can be integrated	
3	Constraint	Tight time allocation and limited technology in schools	Using a block lesson system or cross-subject collaboration
4	Evaluation	Difficulty in changing subjective assessments to objective ones	Development of a more detailed and measurable performance rubric
5	Source of Ideas	Limited creative ideas to create original projects	Conducting digital literacy through social media and implementing (ATM) observe, imitate, modify

Time constraints are the most frequently complained issue, especially by 6th grade teachers. This is due to the demands of completing essential materials and the very busy school exam preparation. 6th grade teachers often have to use other lesson hours or block systems to ensure STEM projects can be completed on time. This situation shows that schedule flexibility is very necessary for project-based learning to run optimally without burdening students. Lack of sufficient duration often prevents the *Improve stage* in EDP from being implemented optimally [22] .

In addition to time, limited technological facilities and infrastructure also pose obstacles in the *technology aspect* of STEM. Fourth and fifth grade teachers noted that the availability of digital devices and internet stability at school was not yet fully equitable for all students. To overcome this, teachers often use simple teaching aids or used materials that are easily found in the surrounding environment. This "low-cost STEM" strategy is implemented so that students can still experiment even without the support of sophisticated technology. However, teachers still hope for more adequate support facilities from school policy [8] .

The assessment aspect also presents a challenge for educators at the school. Teachers find it difficult to objectively assess students' critical thinking processes, especially in heterogeneous group work. The Curriculum Head noted that assessment is often subjective due to the lack of a standardized rubric for engineering skills. Teachers need more specific cognitive and performance assessment instruments to measure the extent to which learning objectives are achieved. This assessment issue is indeed one of the main challenges in implementing the Independent Curriculum in general [6] .

To overcome the idea deadlock, teachers rely on communities and digital platforms for inspiration. The "ATM" (Observe, Copy, Modify) strategy is applied to projects found on YouTube or educational Pinterest. A 6th-grade teacher emphasized that modification is crucial to adapting overseas projects to local wisdom and the availability of materials at school. Furthermore, the school's internal Teacher Working Group (KKG) plays a vital role as a platform for sharing experiences and technical solutions. Collaboration between teachers has been shown to reduce the mental burden of developing complex teaching modules alone [13] .

Based on a comparative analysis between the interview results and the draft teaching module, a very high consistency was found between teachers' perceptions of STEM and the implementation of their planning documents. Teachers at Muhammadiyah 1 Candi Elementary School consistently translated their understanding of interdisciplinary integration into concrete steps in the classroom. In the Grade 4 Teaching Module themed "Disaster Preparedness Bags," teachers successfully integrated scientific concepts about mitigation with efficient packaging techniques. This proves that teachers' statements in interviews regarding the Learning Outcome *Mapping* (CP) technique have been concretely realized in the curriculum document. This consistency is a strong indicator that teachers not only understand the theory superficially, but are also able to apply it in real learning contexts [11] .

At the 5th grade level, consistency is clearly seen in the use of technology as a health campaign medium through the topic "PHBS Agent". In interviews, 5th grade teachers emphasized the importance of the *Technology aspect* in STEM, which was then demonstrated in the teaching module through digital poster creation activities using computers. The document detailed how students used school IT devices to create informative works that had a social impact. This integration shows that teachers consciously utilize the school's computer laboratory facilities to strengthen students' digital literacy. This practice is in line with teachers' perceptions that technology should be a tool to support solutions, not just a complement to material [2] .

The Grade 6 Teaching Module focusing on "Step on Trash Cans" demonstrates consistency in solving pressing environmental issues. Grade 6 teachers stated in interviews that they started designing from real-life problems around the school, such as high waste production. This is reflected in the teaching module which presents an observation activity of the school trash can before students design an engineered product. The use of mathematical concepts in calculating material costs and product dimensions is also seen explicitly in the learning steps. This document proves that teachers are able to synthesize various subjects to address contextual challenges faced by students every day [10] .

the Engineering Design Process (EDP) stages in the teaching module documents is also very much in line with what teachers conveyed during interviews. The three modules systematically include the *Ask, Imagine, Plan, Create,* and *Improve phases* as the main framework for student activities. In the 4th grade module, *the Plan phase* is filled with activities drawing a design of the contents of the bag, while the 6th grade module details the *Create phase* for assembling the tread mechanism. This consistency indicates that the engineering thinking framework has become the standard operating procedure for teachers in developing project-based learning scenarios. This strengthens the finding that the use of a structured EDP model is very helpful for teachers in maintaining the flow of inquiry in elementary grades [5] .

Regarding facility constraints, there is consistency between teacher complaints in interviews and the choice of materials in the teaching modules. Teachers mentioned challenges of cost and availability of equipment, which were then anticipated by using recycled materials in their module drafts. For example, in the step-on trash can project, the module includes the use of leftover wood, bamboo, or other used items as the main materials. This strategy proves that teacher creativity in "low-cost STEM" is not just discourse, but a real action to overcome school limitations. This alignment demonstrates teachers' high adaptability to existing educational infrastructure conditions [14] .

The assessment aspects of the teaching module also reflect the challenges raised by the Curriculum Head regarding the difficulties of objective assessment. Although the module is equipped with an assessment rubric, the criteria used are still dominated by qualitative descriptors that are prone to subjectivity. The 4th grade teacher includes a group work observation sheet that assesses "activeness" and "courage", but the technical criteria for the engineering results are not detailed in depth. The lack of synchronization between the need for precise performance assessment and the instruments available in the module indicates a competency gap in STEM evaluation. This confirms that the development of more specific cognitive and psychomotor assessment rubrics remains a priority for teacher professional development [6] .

However, this study also identified consistent challenges in the assessment aspect of learning. Although teachers stated in interviews that assessing critical thinking skills is very important, analysis of the rubrics in the Teaching Modules showed that the instruments still tend to be general and subjective. The assessment criteria in the modules often use qualitative descriptors that are not able to measure engineering technical progress in depth. This gap confirms the complaint of the Curriculum Head regarding the difficulty of teachers in transforming subjective assessments into objective ones. This indicates that although procedurally learning is already STEM-based, the evaluation side still requires the development of more precise and standardized performance rubrics [1] [23] .

To provide a more concise overview of this consistency comparison, Table 2 presents a cross-analysis between the teachers' verbal data and the teaching module documentary evidence.

Table 2. Consistency Matrix of Teacher Perceptions and Teaching Module Documents.

No	Dimensions of Analysis	Teacher Perception (Interview)	Teaching Module Findings (practice)	Consistency Status
1	Integration of disciplines	Teachers prioritize CP *mapping* to find material intersections	The module includes interrelated disciplines (science, math, tech)	Very consistent
2	Methodology	Using a simplified *Engineering Design*	The activity structure in the module follows	Very consistent

		Process (EDP) framework	*the Ask, Imagine, Plan, Create, Improve phases.*	
3	Utilization of media	Focus on "Low-cost STEM" and use of available IT.	The use of recycled materials (Grade 6) and Computer Lab (Grade 5) are written in the module.	Consistent
4	Contextualization	Topics are taken from real problems in the school environment.	Waste issues and disaster mitigation are the background to the project topic.	Very consistent
5	Assessment	Difficulty assessing critical thinking objectively	The assessment rubric is still qualitative-general, not technical-specific.	Needs improvement

Discussion

Teachers' success in maintaining consistency between their perceptions and documentation of teaching modules is a positive indication of the effectiveness of the collaborative ecosystem in schools. The internal Teacher Working Group (KKG) forum has proven to be a crucial platform for *peer-reviewing* and validating independently prepared module drafts [24]. A study by Salsabiela et al supports this finding by stating that collective support among colleagues can offset the limitations of individual competencies in designing interdisciplinary learning [6]. Therefore, the consistency found at SD Muhammadiyah 1 Candi is not simply the result of personal understanding, but rather the fruit of an institutionalized culture of sharing good practices. This strengthens the argument that curriculum innovation requires ongoing professional social support [22] .

The consistent implementation of the EDP cycle across grade levels (4, 5, and 6) significantly contributes to the development of students' inquiry mindset. Through the *Imagine* and *Plan phases* documented in the module, students are trained to visualize solutions before physically executing them [4] . This practice aligns with constructivist learning theory, which emphasizes the importance of mental planning in the problem-solving process. Consistent inclusion of the *Improve phase* also demonstrates that teachers understand the essence of STEM as an iterative process, not simply the creation of a final product. This is crucial for fostering resilience and a willingness to learn from failure in students from an early age [12] .

However, the lack of synchronization in the assessment instrument aspect indicates a "broken link" in the implementation of STEM in the field. Teachers are capable of designing innovative activities, but are still trapped in conventional, normative evaluation patterns [6] . This gap reflects the need for more specific technical training on the development of performance assessment rubrics based on 21st-century skills indicators [21] . Future research should focus on how to develop authentic assessments that can measure engineering technical skills without neglecting cognitive learning outcomes. Without strong assessment, the sustainability of the quality of STEM learning will be difficult to account for academically [5] .

Overall, the integration of STEM into the Independent Curriculum at this school has been on the right track, despite challenges in time management and facilities. The teacher's strategy in using local materials and modifying overseas projects (ATM) is a form of intelligent adaptation to resource limitations [14] . This proves that facility constraints are not a barrier for teachers who have creativity and a willingness to collaborate. STEM education at the elementary level must continue to be encouraged to be inclusive, relevant, and able to address environmental challenges contextually [10], [13]. School management support in providing time flexibility will be a determining factor for the long-term success of this implementation [22] .

The consistency between perceptions and practices at this school solidifies its position as a school that is adaptive to curriculum changes. The success of developing teaching modules that are in sync with interview results proves that teachers have superior professional competencies in planning. This finding can serve as a model for other elementary schools in initiating STEM implementation through a contextual and collaborative approach [11] . The focus of future development should be directed at improving assessments and optimizing simulation technology to enrich students' learning experiences. With continued synergy, SD Muhammadiyah 1 Candi can continue to be a reference for STEM education innovation in Indonesia [10].

CONCLUSION

Fundamental Finding: The study reveals a strong alignment between teachers' perceptions of the STEM approach and the practical design of teaching modules in elementary schools, where educators successfully transform interdisciplinary concepts into engineering-based learning activities through a structured Engineering Design Process (EDP), supported by Learning Outcome Mapping (CP) and the use of local materials, indicating that teachers' cognitive readiness and the collaborative culture within the Teacher Working Group (KKG) are key drivers of project-based curriculum innovation. **Implication :** This alignment implies that STEM integration has strong potential to reinforce deep learning and character development in accordance with the Independent Curriculum, demonstrating that authentic and meaningful STEM implementation can be effectively achieved through systematic planning, professional collaboration, and contextual learning design. **Limitation :** However, the study also identifies constraints related to limited time allocation and the absence of more objective assessment instruments, as teachers still face challenges in constructing rubrics that accurately measure students' critical thinking and creativity across engineering stages, while dependence on school technological facilities restricts inclusive learning adaptation strategies. **Future Research :** Future research is encouraged to examine the broader impact of STEM module implementation on scientific literacy and quantitative learning outcomes, as well as to explore block scheduling for STEM projects, the development of a validated STEM Project Bank, and intensive training for performance-based assessment rubrics aligned with international standards, particularly in relation to strengthening assessment quality and time management for sustainable STEM-based learning in elementary schools.

REFERENCES

[1] A. B. Intan and F. F. W. Setyowati, "Efektivitas Integrasi Kurikulum STEM di Sekolah Indonesia," *Educ. Sci. J. Educ.*, vol. 2, pp. 135–144, 2024, [Online]. Available: https://journal.csspublishing.com/index.php/education

[2] M. I. R. A. of S. B. L. in E. S. within the F. of the M. C. A. Siti Faridah, Ridho Indra Saputra, "ANALISIS PEMBELAJARAN STEAM DI SEKOLAH DASAR BERBASIS KURIKULUM MERDEKA," *Anterior J.*, vol. 24, no. III, pp. 114–119, 2025.

[3] A. W. Hana Janatan Salsabiela, Ririn Dwiyanti, Valentina Setiyawati, "ANALISIS KESIAPAN GURU DALAM MENGIMPLEMENTASIKAN PENDEKATAN STEM," *J. Sekol. PGSD*, vol. 9, no. 1, pp. 17–28, 2024.

[4] J. B. K. Alfina Damayanti, "MODEL STEM UNTUK MENINGKATKAN KEMAMPUAN PEMECAHAN MASALAH SISWA KELAS V SEKOLAH DASAR," *J. Prof. Elem. Educ.*, vol. 4, no. 1, pp. 1–120, 2025.

[5] S. T. Lestari, D. A. Uswatun, and A. Sutisnawati, "Pengembangan Instrumen Penilaian Kognitif Siswa Berbasis STEM EDP pada Mata Pelajaran IPA di Sekolah Dasar," *J. Kependidikan*, vol. 14, no. 1, pp. 813–826, 2025.

[6] H. Gabriel Serani, "IMPLEMENTASI ASESMEN PEMBELAJARAN KURIKULUM MERDEKA : KESULITAN DAN TANTANGAN GURU DI SEKOLAH DASAR," *J. Ilm. Ilmu Pendidik.*, vol. 15, no. April, pp. 79–90, 2024.

[7] A. U. Akmal, A. K. Kenedi, I. Muthie, and R. Novariza, "Pelatihan Integrasi Deep learning , Flipped classroom , dan STEAM untuk Guru Sekolah Dasar," *J. Pengabdi. Masy.*, vol. 5, pp. 1270–1277, 2025.

[8] S. K. Handayanto, M. L. Oktarianto, A. D. Yasa, E. Setiyawati, and N. Isbandrianingtyas, "Pelatihan Pembelajaran S TEM d i Sekolah Dasar Untuk Mengembangkan Keterampilan Abad 21," *J. DIKEMAS (PENGABDIAN Kpd. MASYARAKAT)*, vol. 6, no. 1, pp. 12–19, 2022.

[9] M. S. Abdullah, "PENERAPAN PENDEKATAN STEM DALAM PEMBELAJARAN IPA UNTUK MENINGKATKAN KETERAMPILAN BERPIKIR KRITIS SISWA KELAS 5 SD," *J. Ris. Ilm.*, vol. 2, no. 4, pp. 2014–2022, 2025.

[10] B. Setiawan, I. R. Kurnia, D. N. Hafifah, and V. Iasha, "Pendekatan STEM untuk Meningkatkan Literasi Lingkungan dan Kesadaran Sosial-Ekologis Siswa Sekolah Dasar Berbasis Tujuan Pembangunan Berkelanjutan (SDGs)," *Int. J. Educ. Learn. Stud.*, vol. 6, no. April, pp. 49–62, 2025.

[11] T. Hartina, I. Ningsih, R. Ekawati, and S. R. Kusumaningrum, "EKSPLORASI PENERAPAN STEM DALAM PEMBELAJARAN IPAS DI SEKOLAH DASAR : STUDI KASUS DI MI RIYADLUL ULUM," *J. Ilm. Pendidik. IPA*, vol. 7, no. 3, pp. 1430–1440, 2025.

[12] A. G. Lilik Mustofiyah, Fitri Puji Rahmawati, "PENGEMBANGAN KURIKULUM BERBASIS STEM UNTUK MENINGKATKAN KOMPETENSI SISWA DI ERA DIGITAL: TINJAUAN SYSTEMATIC LITERATURE REVIEW," *J. Ilm. Pendidik. Dasar*, vol. 09, no. 3, pp. 1–22, 2024.

[13] B. Setiawan, A. Barokah, D. Nugroho, A. E. Wihara, N. Nurezalita, and M. S. Zulela, "MENINGKATKAN KOMPETENSI GURU MELALUI PELATIHAN P5 BERBASIS STEM : WORKSHOP KELOMPOK KERJA GURU SEKOLAH," *J. Pengabdi. Kpd. Masy.*, vol. 5, no. 1, pp. 70–78, 2025.

[14] R. Gusmida, S. Barokah, and N. Hermita, "No Student Left Behind ? Tantangan dan Solusi Pendidikan STEM Inklusif di Sekolah Dasar," *Golden Age Incl. Educ.*, vol. 2, no. 2, pp. 89–97, 2025.

[15] M. Y. Ningsih, N. Efendi, and S. B. Sartika, "Pengaruh Model Project Based Learning Terhadap Berpikir Kreatif Peserta Didik dalam Pembelajaran IPA," *J. Inov. Pendidik. Sains*, vol. 2, no. 2, pp. 42–51, 2021.

[16] N. Andini, A. S. Assholehah, C. Nisa, and F. S. Arifiana, "Analisis Penggunaan Aplikasi Quizizz Fitur Mode Kertas Sebagai Media Asesmen Formatif Dalam Meningkatkan Hasil Belajar IPAS SD," *J. Ilm. Penelit. Mhs.*, vol. 3, no. 1, pp. 373–383, 2025.

[17] M. S. Vitra Nailinda, Jesi Alexander Alim, "IMPLEMENTASI PEMBELAJARAN STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) TERHADAP KETERAMPILAN BERPIKIR KRITIS SISWA SEKOLAH DASAR," *J. Inov. Pendidik. Mat. dan IPA*, vol. 5, no. 1, pp. 363–374, 2025.

[18] B. Y. W. Ni Made Yeni Suranti, "PROJECT BASED LEARNING DENGAN PENDEKATAN STEM PADA PENDIDIKAN SEKOLAH DASAR," *Indones. J. Elem. Child. Educ.*, vol. 5, no. 3, pp. 98–104, 2024.

[19] M. Syarifuddin, Ika Wirahmad, "Efektivitas Pendekatan STEM Berbasis Collaborative Learning terhadap Pemahaman Konsep Abstrak Siswa Sekolah Dasar," *Bima J. Elem. Educ.*, vol. 3, no. 1, pp. 1–9, 2025.

[20] S. Amelia, E. J. Wicaksana, and D. Mursyd, "Essay Test Integrated with Socio- Scientific Project-Based Learning for Scientific Argumentation," *Pedagog. J. Pendidik.*, vol. 14, no. 2, 2025, doi: 10.21070/pedagogia.v14i2.1949.

[21] Nurhalimah and E. H. Hermaliani, "Analisis Penerimaan dan Penggunaan Teknologi Google Classroom Sebagai Media Pembelajaran Menggunakan Technology Acceptance Model (TAM) Dan Delone-McLean," *JASIKA (Jurnal Sist. Inf. Akuntansi)*, vol. 3, no. 2, pp. 73–83, 2023.

[22] L. F. Yuyun Elizabeth Patras, Clarissa Yolanita, Diki Akmal Wildan, "Pembelajaran Berbasis STEM di Sekolah Dasar Guna Meningkatkan Kemampuan Berpikir Kritis Dalam Rangka Menyongsong Pencapaian Kompetensi Siswa Abad 21," *J. Ilm. Kependidikan*, vol. 12, 2024.

[23] A. F. Trinanda Zalsa, "Studi Literatur: Efektivitas Pendekatan STEM dalam Meningkatkan Kemampuan Berpikir Kritis Siswa Sekolah Dasar," *J. Jendela Pendidik.*, vol. 5, no. 01, pp. 174–183, 2025.

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