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How Do Teachers Implement STEM Components? Analysis Variations Implementation in Lesson Plans After STEM Training

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Abstract: This study aims to analyze the variation in the application of Science, Technology, Engineering, and Mathematics (STEM) components in the Lesson Plans prepared by junior high school teachers after participating in STEM training. This study uses a qualitative approach with document analysis methods on 39 lesson plans of science and mathematics teachers in Bangkalan Regency. The data were analyzed by identifying the presence and form of implementation of each STEM component, then grouping the lesson plans based on the number of integrated components—namely, two, three, and four STEM components. The results showed that 6 lesson plans (15.4%) integrated two STEM componentsScience and Mathematics—which generally focused on conceptual understanding and mathematical calculations, while 11 lesson plans (28.2%) integrated three STEM components with various combinations of Science-Technology-Mathematics (STM), Science-Engineering-Mathematics (SEM), and Technology-Engineering-Mathematics (TEM). The majority of lesson plans—22 (56.4%)—fully integrated all four STEM components into their instructional planning. The findings indicate that most teachers were able to integrate all four STEM components into their lesson plans following the training. Variations in the application of STEM components reveal differing tendencies in the selection and integration of these components in teachers' lesson plans after the training. This study provides an empirical overview of the patterns of integration of STEM components in teachers' lesson plans following the training.

INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics) education is gaining attention in curriculum development and learning practices in Indonesia in line with 21st-century education demands that emphasize problem-solving skills, critical thinking, collaboration, and creativity. STEM is understood as a learning approach that integrates various disciplines to support the development of these competencies (Dwita & Susanah, 2020). This approach is considered strategic because it integrates various disciplines to bridge theoretical concepts with real-world applications, making learning more contextual and meaningful for students. Various international studies show that integrated STEM learning contributes positively to improving the quality of learning and preparing students to face complex global challenges (Huang et al., 2022; Yang & Ball, 2024). The STEM approach can serve as an alternative for bridging the gap between abstract mathematical concepts and students' conceptual understanding through their application in the context of real-world problems (Sa'adah & Rahaju, 2026). In the Indonesian context, STEM implementation began

to be developed with consideration given to its suitability for the national curriculum and the strengthening of local contexts as relevant learning resources (Herliani et al., 2021). In line with this, the government and educational institutions are intensively promoting training programs for teachers to improve their competence in designing and implementing STEM-based learning in accordance with modern curriculum requirements. A number of findings from empirical studies and teacher capacity building programs indicate that the appropriate design and implementation of STEM has the potential to significantly improve students' science literacy and mathematical reasoning (Lafifa et al., 2023).

To address the need to enhance teachers' competencies in implementing STEM education, various STEM training programs for teachers have been widely organized as a strategy for continuous professional development. These training programs are designed to enable teachers to integrate STEM components into lesson planning—such as lesson plans and student worksheets—and to effectively apply them in classroom learning activities. Various studies and training program reports indicate a range of support provided, ranging from workshops on STEM-based lesson plan design, guidance on developing assessment instruments, to mentoring on the use of technology and simple tools to support learning activities. Training designed through a combination of training and mentoring models has been reported to enhance teachers' practical skills in developing STEM-integrated instructional materials and assessment instruments. Therefore, research examining lesson plans produced after the training serves as a strategic step to more objectively assess the actual outcomes of the training program's implementation (Diana et al., 2025). Consistent with these findings, several studies indicate that STEM-based professional development significantly contributes to improving the quality of lesson plans and teachers' readiness to integrate STEM into their instruction (Gümüş & Altan, 2025; Mumcu et al., 2023).

The Science, Technology, Engineering, and Mathematics (STEM) approach is understood as an integrated learning approach that systematically combines the four disciplines to build conceptual and practical understanding through real-world contexts (Mufitdah & Erny, 2024). The integration of STEM in learning is not interpreted as the partial combination of science, technology, engineering, and mathematics subjects, but rather as the integration of interconnected components in a series of learning activities oriented towards authentic problem solving. Integrated STEM learning is characterized by the use of real-world problems as the main context of learning, so that students are encouraged to meaningfully connect cross-disciplinary concepts in the process of finding solutions (Dare et al., 2021). Through this approach, each STEM component does not stand alone, but complements and interacts functionally with one another, where science plays a role in understanding phenomena, technology is utilized as a tool or supporting medium, engineering is realized through the process of designing solutions, and mathematics is used for analysis and data-based decision making.

STEM-based Lesson Plans are learning planning tools designed to facilitate the integration of Science, Technology, Engineering, and Mathematics components into a comprehensive and structured learning scenario. A number of studies show that the quality

of STEM-based lesson plans is not solely determined by the administrative completeness of the learning components, but rather by the level of integration between STEM components in relating the context of the problem, the learning process, and the products or outputs produced by students (Arivina & Jailani, 2020; Nefianthi et al., 2022). The main characteristics of STEM lesson plans include the use of contextual problems as learning triggers, the application of the engineering design process which includes the stages of problem identification, design, creation, and evaluation of solutions, and the existence of products or artifacts as the result of student learning activities (Hoerunnisa et al., 2024). Furthermore, studies on STEM-based lesson plan design emphasize that the minimum criteria for implementing STEM in lesson plans must include at least two meaningfully integrated STEM components, since symbolic integration—such as merely listing the use of technology without a clear pedagogical function—does not reflect the true implementation of STEM learning (Nipyrakis et al., 2025). Several studies also confirm that many lesson plans currently in use incorporate only two or three components, even though they are still labeled as STEM (Rahmaniar et al., 2024; Sokha & KINYA, 2023; Toma et al., 2024). Therefore, an analysis of STEM-based lesson plans must go beyond merely identifying the presence of STEM components; it must also map the variations in the number and combinations of components applied and describe how each component is operationalized within the learning sequence.

Many studies in the last five years have highlighted the implementation of STEM learning in Indonesia, with a primary focus on its impact on student learning outcomes, such as improved critical thinking skills, creativity, science literacy, and 21st-century skills. These studies generally use experimental designs and research and development to assess the effectiveness of STEM-based learning models, such as Project Based Learning or STEM module development, with success indicators centered on student learning outcomes (Reyza et al., 2020; Thovawira et al., 2021). In addition, literature reviews show that STEM implementation in Indonesia is largely directed at developing learning tools, such as STEM-based modules, student worksheets, and lesson plans, with the aim of improving the quality of learning and supporting the strengthening of students' 21st-century skills (Wahyuni et al., 2022). Studies on the development of STEM-based instructional materials generally report that the resulting products are considered valid and suitable for use; however, the focus of such research remains limited to the quality of the developed products, rather than to the variations in the integration of STEM components that naturally emerge in teachers' lesson planning after they have completed training (Wahyuni et al., 2022). On the other hand, studies examining the effects of implementing STEM-based learning models or tools have primarily focused on their impact on student learning outcomes—such as improvements in critical thinking, problem-solving, and science literacy—without delving deeply into how the components of Science, Technology, Engineering, and Mathematics are concretely integrated into the lesson plans developed by teachers. This situation indicates that although research on the development and impact of STEM learning has advanced significantly, there remains a lack of studies that specifically analyze variations in the

application of STEM components in teachers' lesson plans following training—as authentic evidence of STEM implementation during the instructional planning phase.(Hoerunnisa et al., 2024).

This study stems from the central question of how teachers incorporate STEM (Science, Technology, Engineering, and Mathematics) components into their Lesson Plans developed after participating in STEM training, given that STEM implementation in Indonesia has thus far been studied primarily in terms of student learning outcomes and the development of instructional materials. The objective of this study is to analyze variations in the application of STEM components in teachers' post-training, both in terms of the number of components integrated and the identification of interrelationships among STEM components. A number of previous studies have shown that STEM research generally focuses on the validity of worksheets or lesson plans, or on the impact of STEM learning on students' critical thinking skills and science literacy, while the analysis of teachers' lesson plans as authentic evidence of STEM implementation is still relatively rare (Hoerunnisa et al., 2024). Therefore, this study is expected to provide practical benefits for teachers as a basis for reflection in identifying variations in the application of STEM components in lesson planning; for training organizers as a basis for program evaluation and the design of follow-up training that better aligns with teachers' needs; and for researchers as an empirical contribution to enriching the literature on the implementation of STEM through the analysis of lesson planning documents in the context of Indonesian education.

METHOD

This study employs a descriptive qualitative approach using document analysis, given that the focus of the study is on examining the content of STEM-based Lesson Plans as products of instructional planning developed by teachers after participating in STEM training. Document analysis was chosen to systematically uncover how the components of Science, Technology, Engineering, and Mathematics are integrated into the Lesson Plans, rather than to directly measure student learning outcomes. This approach aligns with the view that document analysis is an effective qualitative research technique for interpreting the meaning, structure, and patterns contained in educational documents (Bowen, 2009). Furthermore, the research approach in this study is consistent with studies that analyze STEM-based lesson plans as a representation of curriculum implementation, as well as with international studies that emphasize the importance of analyzing lesson plan design to understand the conceptual practice of STEM integration (Nipyrakis et al., 2025; Rahmaniar et al., 2024).

The data sources for this study consisted of 39 STEM-based Lesson Plans (RPP) developed by science and mathematics teachers in Bangkalan Regency after participating in STEM training. These 39 RPPs constitute all the lesson plan documents collected from the training participants and were available for analysis at the time the study was conducted. Lesson plans were selected as the primary data source because they reflect both teachers' pedagogical understanding and their ability to translate STEM concepts into structured and

systematic lesson planning. Analysis of these lesson plans allowed the researcher to identify patterns and variations in the integration of STEM components within a relatively homogeneous curriculum context. The use of lesson plans as units of analysis is also widely applied in international research because they can conceptually represent the quality of STEM instructional design prior to its implementation in the classroom.(Nipyrakis et al., 2025). In addition, educational research at the elementary school level shows that instructional planning documents, such as lesson plans, play a crucial role in assessing teachers' understanding of STEM project-based learning, in line with a study published in a SINTA 3 journal that emphasizes the importance of document analysis in evaluating the implementation of innovative teaching approaches (Huda et al., 2025; Le et al., 2023).

The research instrument consists of an analysis sheet for STEM-based Lesson Plans (RPP), developed by adapting the indicators of STEM component integration and tailored to the research focus (Rahmaniar et al., 2024). The instrument was developed by defining the four main components of STEM as categories for analysis, then formulating indicators that can be explicitly identified in lesson plan documents, including scientific concepts and processes in science; the application of technology and its pedagogical functions in Technology; design processes and products/artifacts in Engineering; and the use of mathematical concepts and analysis in Mathematics. The analysis sheet presented in Table 1 includes the four main components of STEM—Science, Technology, Engineering, and Mathematics—which are analyzed based on their presence and forms of implementation in the planned learning activities. This component-based analytical approach allows researchers to describe variations in the number and combinations of STEM components that appear in each lesson plan and to describe how each component is applied within the learning sequence. The document analysis instrument enables researchers to systematically identify both the presence and forms of STEM components in lesson plans (RPP), going beyond mere component detection to characterize how STEM is operationalized in instructional planning (Chamrat & Suyamoon, 2024; Nipyrakis et al., 2025; Nugroho et al., 2022). Furthermore, research that utilized lesson plan analysis to measure the quality of STEM-based science instruction planning through indicators of Technological Pedagogical Content Knowledge (TPACK) and interdisciplinary integration showed that lesson plan documents can be used to identify the application of STEM elements and teachers' readiness to design integrated instruction (Sari & Mega, 2022).

The data analysis technique in this study was conducted through several systematic and iterative stages. In the first stage, the researcher identified the presence of each STEM component (Science, Technology, Engineering, and Mathematics) in each lesson plan using a specially developed analysis sheet. In the second stage, each identified STEM component was coded (S, T, E, and M) to facilitate the categorization process and the mapping of integration patterns among components. The coding process was conducted independently by the researcher on all 39 lesson plan documents using pre-established coding guidelines and analysis indicators. To ensure coding consistency, the researcher cross-checked the classification results by verifying each coding decision against the operational definitions

and evidence of activities listed in the lesson plans. Subsequently, the lesson plans were grouped based on the number of STEM components applied: those integrating two, three, and four STEM components. The next stage involved interpreting the findings to explain variations in the implementation of STEM in teachers' lesson plans—both in terms of the number and combination of components applied—and to describe how each component was implemented in the planned learning activities. The results of the subsequent analysis were used to identify trends in STEM implementation patterns that emerged in the lesson plans developed after the training. This approach allows researchers to gain insight into which STEM components appear most frequently and least frequently, as well as the various combinations of components used by teachers. This analytical approach aligns with findings from a systematic review, which confirms that analyzing patterns of STEM component integration in instructional documents is a crucial step in evaluating the effectiveness of instructional planning and teachers' pedagogical readiness to implement STEM-based learning (Le et al., 2023).

Table 1. STEM-based Learning Implementation Plan Analysis Instrument

STEM Components	Analysis Indicators	Description	There is	There isn't
Science (S)	Scientific concepts are used to understand phenomena	The lesson plan contains concepts, principles, or science phenomena that are relevant to the contextual issues discussed in the lesson.		
	Scientific process	The lesson plan facilitates activities such as observing, questioning, collecting data, or analyzing phenomena.		
Technology (T)	The use of technology as a tool	Lesson plans uses technology (digital/non-digital) as a medium, measuring tool, simulation, or learning support tool.		
	The pedagogical function of technology	Technology is used to support conceptual understanding or problem solving, not just presentation.		
Engineering (E)	Solution design process	The lesson plan contains the stages of the engineering design process (problem identification, design, creation, testing, evaluation).		
	Product	Lesson plans produces products or models as solutions to given problems.		
Mathematics (M)	Use of mathematical concepts	The lesson plan uses mathematical concepts (calculations, formulas, data representation) to solve problems.		
	Data-driven analysis	Mathematics is used for analysis, decision making, or evaluation of solutions.		

RESULT AND DISCUSSION

The analysis of 39 lesson plans prepared by junior high school teachers participating in STEM training in Bangkalan Regency shows variations in the application of Science, Technology, Engineering, and Mathematics components in the lesson planning stage. In general, the analyzed lesson plans can be grouped into three categories based on the number

of integrated STEM components, namely lesson plans with two STEM components, three STEM components, and four STEM components. These findings indicate that the implementation of STEM by teachers has not been uniform, even though all teachers have participated in the same training program. This variation reflects differences in teachers' conceptual understanding and pedagogical abilities in integrating STEM components into planned learning scenarios, as also shown in previous studies (Rahmaniar et al., 2024).

Table 2. Results of STEM Component Analysis in Lesson Plans

Variations in the Application of STEM Components	Component Combination	Number of lesson plans	Percentage (%)	Total Percentage (%)
2	S-M	6	15,4	15,4
3	S-T-M	3	7,7	28,2
	S-E-M	6	15,4	
	T-E-M	2	5,1	
4	S-T-E-M	22	5,6	56,4
Total		39	100	100

Of the 39 lesson plan documents analyzed, 6 (15.4%) integrated two STEM components: Science and Mathematics (S-M). Lesson plans in this category generally emphasize the understanding of scientific concepts combined with the use of mathematical calculations to solve problems or complete planned learning tasks. In the Science and Mathematics (S–M) model, the Science component serves as the foundation for understanding contextual phenomena or problems, while Mathematics is used to analyze data, apply mathematical concepts, or explain situations related to those problems. One lesson plan that applies the Science and Mathematics (S–M) components addresses the topic of energy efficiency in household lighting: the Science component is used to explain the concept of electrical energy, analyze the efficiency of various types of light bulbs, and conduct experiments to test energy consumption, while Mathematics is used to analyze comparisons of energy consumption, calculate electricity costs, and create graphs illustrating the relationship between power, time, and cost. The interconnection between these two components is also supported by research indicating that while teachers find it easier to link science and mathematics, they often struggle to clearly incorporate technology and engineering into their lesson planning (Rahimah et al., 2023). However, in the lesson plans in this category, no use of technology with a clear pedagogical function was found, nor were there any solution-design stages that reflected the engineering design process. These findings indicate that some teachers still interpret STEM as the reinforcement of science learning supported by mathematics, without integration with technology and engineering components, as was also identified in previous studies (Dare et al., 2021).

A total of 11 lesson plans (28.2%) fell into the category of implementing three STEM components with varying combinations of integration: 3 lesson plans that integrated Science-Technology-Mathematics (STM), 6 that integrated Science-Engineering-Mathematics (SEM), and 2 that integrated Technology-Engineering-Mathematics (TEM). In the STM combination, the science component serves as the foundation for understanding phenomena, while Mathematics is used to process data or perform calculations related to those phenomena. Lesson plans with the STM combination generally utilize technology as

a medium or tool to visualize scientific and mathematical concepts; however, they do not explicitly involve the process of designing solutions, as is characteristic of engineering-based learning. In the SEM combination variation, science provides the conceptual foundation for a problem; engineering is used to design solutions; and mathematics is used to determine dimensions, calculate requirements, or evaluate design outcomes. Lesson plans with the SEM combination demonstrate teachers' efforts to engage students in activities involving the design or creation of simple products based on scientific concepts and supported by mathematical calculations. In the TEM combination approach, Technology is used as a tool or means to support the learning process and problem-solving; Engineering is applied through the design, creation, testing, or development of a solution; while Mathematics is used to support the measurement, calculation, analysis, or evaluation of the designed solution. Meanwhile, lesson plans incorporating the TEM combination are relatively rare and tend to focus on the use of technology and the product design process supported by mathematical calculations; however, the scientific context as the conceptual foundation of learning has not been explored in depth, as also noted in previous studies. (Nipyrakis et al., 2025).

The category involving the application of the four STEM components (Science, Technology, Engineering, and Mathematics) was the most prevalent, comprising 22 lesson plans (56.4%). Lesson plans that incorporated all four STEM components demonstrated variations in how each component was applied and how they were interconnected within the learning process. In these lesson plans, Science is used to understand the concepts or phenomena underlying the problem; Technology is utilized as a tool or medium to support the problem-solving process; Engineering is manifested through activities involving the design and testing of solutions; and Mathematics is used for calculations, data analysis, or decision-making. One of the lesson plans addressed the issue of water quality and guided students to design a simple water filtration device using sand, gravel, charcoal, and filter cloth. The Science component is evident through lessons on suspended particles and the principles of filtration and adsorption, while Technology is manifested through the use of bottles, funnels, and simple materials as filtration technology. The Engineering component is more explicitly evident through the stages of identifying device requirements, creating initial sketches, developing designs and flowcharts, building prototypes, testing the device's effectiveness, and refining the design based on test results. Meanwhile, mathematics is used to measure the volume of water and filtration time, as well as to compare the results before and after filtration using simple tables or graphs. Thus, the presence of these four components is assessed not only by their inclusion in the lesson plans but also by the function of each component and how they interrelate to support problem-solving. These findings indicate that the implementation of full STEM must be understood based on the functional relationships among the components, rather than solely on the number of components listed in the lesson plans.

The predominance of lesson plans that integrate the four STEM components (56.4%) indicates that the STEM training attended by teachers resulted in lesson plans where the

application of all four STEM components was the most common pattern observed post-training. However, the presence of all four components in a lesson plan does not necessarily mean that all components have been fully integrated, as integration must be assessed based on the relationships and functions of each component within the learning sequence. Therefore, the finding of 22 lesson plans with all four STEM components can be viewed as a reflection of the dominant pattern of STEM implementation during the post-training lesson planning phase, while the quality of integration among the components needs to be analyzed based on the functional relationships demonstrated in each lesson plan. Furthermore, based on data regarding variations in the combinations of STEM components, it was found that mathematics was consistently included—consistent with research indicating that the mathematics component is often present more frequently than science, technology, and engineering (Forde et al., 2023). However, another study analyzing 31 modules found that the science component appeared 100% of the time, technology 77%, mathematics 61%, and engineering only 23% (Hermanto et al., 2025).

The analysis also revealed lesson plans that integrated only two or three STEM components. The dominant pattern of two-component lesson plans—involving only science and mathematics—indicates that some teachers still tend to interpret STEM as merely a reinforcement of science and mathematics instruction. This finding is consistent with studies indicating that teachers often face difficulties in authentically integrating engineering and technology, thereby reducing STEM learning to a partial multidisciplinary approach (Dare et al., 2021). These two components do not always appear alongside Science and Mathematics, as their application must be tailored to the characteristics of the subject matter, the problems at hand, and the designed learning objectives. Typically, many teachers feel they lack the competence to teach using an approach that integrates science, technology, engineering, and mathematics, particularly in fields outside their original areas of expertise (Ellebæk et al., 2024; Hamad et al., 2022; Yoon et al., 2026). Consequently, the engineering and technology components are often considered the most difficult to integrate into regular lessons (Aslam et al., 2023; García-Carmona & Toma, 2024; Kaya & Akyüz, 2024).

The variety of combinations in lesson plans involving the three STEM components (STM, SEM, and TEM) reflects transitional stages in teachers' understanding and competence regarding the implementation of STEM learning. The predominance of lesson plans combining Science-Engineering-Mathematics (SEM) in this category indicates that teachers find it relatively easier to integrate engineering aspects through design or product-making activities than to integrate technology pedagogically. This finding aligns with research revealing that teachers tend to be more confident in implementing the engineering design process when it is linked to concrete activities, yet they still face challenges in meaningfully utilizing technology as part of the learning process (Mumcu et al., 2023). Thus, the variations in the application of the three STEM components can be understood as phases in the development of teachers' competencies toward a more holistic and authentic integration of STEM.

CONCLUSION AND SUGGESTIONS

Based on the analysis of 39 lesson plans developed by junior high school teachers in Bangkalan Regency following STEM training, it can be concluded that the implementation of the Science, Technology, Engineering, and Mathematics components in lesson planning exhibits varying degrees of integration. The majority of the lesson plans—22 documents (56.4%)—included all four STEM components: Science, Technology, Engineering, and Mathematics. These findings indicate that the pattern of implementation across all STEM components is the most dominant pattern in teachers' lesson plans following the training, although the presence of all four components does not necessarily imply complete integration. On the other hand, variations were also found in the number and combination of STEM components applied in the lesson plans: specifically, two and three STEM components, with 6 lesson plans (15.4%) integrating two STEM components—namely, Science and Mathematics (S-M)—and 11 lesson plans (28.2%) fall into the category of applying three STEM components with varying integration combinations: 3 lesson plans integrating Science-Technology-Mathematics (STM), 6 integrating Science-Engineering-Mathematics (SEM), and 2 integrating Technology-Engineering-Mathematics (TEM). These variations indicate that the application of STEM in lesson planning does not always involve all four components simultaneously but can be adapted to the characteristics of the concepts, problems, and learning objectives designed by the teacher. Therefore, the presence of only two or three STEM components cannot be directly viewed as a limitation in the implementation of STEM, as the interrelationships among the components must be assessed based on the relevance of each component to the learning materials and activities. Thus, the research findings indicate variations in the implementation of STEM following the training; however, these findings are not yet sufficient to conclude the effectiveness of the training in improving teachers' competencies.

Based on these findings, future STEM training for teachers should not only focus on the administrative preparation of lesson plans, but also strengthen teachers' conceptual understanding and practical skills related to the role of technology and engineering as meaningful learning processes. Teachers need to be encouraged to functionally link the four components of STEM through the use of contextual problems, the application of solution design processes, and the use of technology with clear pedagogical objectives. In addition, further research can develop this study by combining an analysis of lesson plan documents and a study of classroom learning implementation, thereby obtaining a more comprehensive picture of the quality and consistency of STEM learning practices in schools.

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