MATHEdunesa
Homepage: https://ejournal.unesa.ac.id/index.php/mathedunesa/index
Email: mathedunesa@unesa.ac.id
p-ISSN: 2301-9085; e-ISSN: 2685-7855
Vol. 15 No. 3 Tahun 2026
Halaman 597-612

Transforming Junior High School Teachers' Basic STEM Knowledge through Training to Strengthen STEM-Based Mathematics Learning

Faradiba Izzati Sa'adah[1*], Endah Budi Rahaju[1]

[1]Mathematics Education Department, Universitas Negeri Surabaya, Surabaya

DOI: https://doi.org/10.26740/mathedunesa.v15n3.p597-612

Article History:
Received: 22 December 2025
Revised: 28 April 2026
Accepted: 20 June 2026
Published: 19 July 2026

Keywords:
Basic STEM Knowledge; Junior High School; Mathematics Learning; Teachers; STEM; Teacher Training

***Corresponding author:**
faradiba.23257@mhs.unesa.ac.id

Abstract: The implementation of STEM *(Science, Technology, Engineering, and Mathematics)* based mathematics learning depends on teachers' conceptual understanding of interdisciplinary integration. Although STEM has been widely introduced through training programs, prior studies indicate that junior high school mathematics teachers' understanding remains partial. This study aims to describe how STEM training transforms teachers' understanding in conceptual, applicative, and affective aspects. This study used a qualitative descriptive design with a pretest–posttest approach, analyzing teachers' responses through content analysis to identify patterns of conceptual change. The study involved 30 junior high school mathematics teachers selected through purposive sampling. Data were collected using pretest and posttest open-ended essay questions and analyzed through coding and thematic categorization. The findings revealed that before the training, most teachers perceived STEM merely as a combination of subjects, without clearly understanding how science, technology, engineering, and mathematics are integrated through problem-solving processes, design activities, and specific learning objectives. After the training, a clear shift occurred, with most teachers developing more accurate and integrated conceptions of STEM. They were able to explain STEM as an interdisciplinary approach focused on problem solving rather than subject integration alone. In practice, most teachers reached a contextual level of implementation by providing authentic examples such as real-world problem-solving activities, simple engineering design tasks, and the integration of mathematical calculations and technology. Teachers' confidence also increased significantly, indicating greater readiness to implement STEM-based learning. These findings highlight the importance of continuous and well-designed STEM training program.

INTRODUCTION

Mathematics learning at the junior high school level still faces a variety of complex challenges, especially related to students' ability to understand abstract concepts. This is evidenced by the fact that some students have difficulty understanding mathematical symbols and relating them to concrete situations (Kusmaryono et al., 2024). This condition can result in low reasoning skills and weak abilities in applying mathematical concepts in everyday contexts. In addition, the findings of the 2022 OECD Programme for International Student Assessment (PISA) also show that Indonesian students' mathematics performance is below the OECD average, with Indonesia ranking 68th with a score of 366 (OECD, 2023), especially in the aspects of concept application and numeracy-based information interpretation. This score gap indicates that Indonesian students' mathematical abilities particularly in terms of applying concepts and interpreting numeracy-based information remain relatively low compared to those of students in other countries. This situation emphasizes the importance of learning innovations that can provide concrete, meaningful learning experiences that are relevant to students' real lives.

In response to the challenges posed by students' limited ability to grasp abstract mathematical concepts, their difficulty in connecting symbols to real-world contexts, and their weak reasoning skills and ability to apply concepts in daily life, the STEM *(Science, Technology, Engineering, and Mathematics)* approach has emerged as a strategic alternative to bridge the gap between mathematical abstraction and students' conceptual understanding. The STEM approach is understood as an interdisciplinary approach that combines the four components of STEM, namely science, technology, engineering, and mathematics in the learning process, with an emphasis on problem solving rooted in real situations so that concepts are not studied separately from their context (Ardiyansyah et al., 2020; Dwita & Susanah, 2020; Saputri & Herman, 2022). This approach is also in line with the objectives of developing 21st-century competencies, in which students are required to have critical thinking skills, problem-solving skills, and readiness to adapt to ever-evolving technological changes (AlAli, 2024). In mathematics education, STEM integration enables students to connect numerical and symbolic concepts with practical applications through exploration, design, and simple engineering. Thus, the implementation of STEM not only strengthens students' conceptual understanding but also helps teachers design learning experiences that are more contextual, relevant, and aligned with today's needs.

A few numbers of studies reinforce the effectiveness of the STEM approach in improving the quality of mathematics learning in schools. This approach has been proven to improve students' creative and critical mathematical thinking skills through exploration, design, and problem-solving activities that provide space for independent understanding (Rahmawati & Ndori, 2022). These findings are reinforced by the results of other studies showing that STEM-based learning methods are more effective than conventional methods, as seen from the consistently higher achievement scores of students in classes that implement STEM learning than those still using conventional approaches (Kong & Matore, 2022). Research on the STEM-PjBL model also confirms a significant increase in students' mathematical creative thinking skills, as project integration helps enrich the learning process and strengthen higher-order thinking skills (Ferdiansyah et al., 2025). Overall, this series of studies shows that the STEM approach not only improves academic achievement but also strengthens essential 21st-century mathematics learning competencies.

However, the implementation of STEM in Indonesia still faces significant structural and pedagogical challenges. A survey of 50 mathematics teachers showed that although the majority of teachers recognized the importance of STEM-based learning, many of them felt unprepared and did not fully understand the concepts, principles, and procedures for its application in the classroom (Sari & Juandi, 2021). Similar findings were found in a survey of 20 junior high school mathematics teachers in Donggala Regency, Central Sulawesi, which showed that most teachers only knew the acronym STEM without having a deep understanding of the concept or steps for its implementation (Mubarik et al., 2022). This challenge is exacerbated by limited access to technology, learning tools, and learning resources, especially in areas with limited resources. These conditions make it difficult for teachers to design appropriate STEM activities, especially given the lack of training, uneven distribution of laboratory facilities, and lack of STEM-based teaching materials. As a result, the implementation of STEM at the junior high school level has been inconsistent and tends to be carried out only by teachers who take personal initiative.

One effort to address this issue is through the implementation of teacher training designed to strengthen conceptual understanding and pedagogical skills related to STEM. This type of training has been increasingly implemented in recent years in line with the implementation of the Merdeka Curriculum, which emphasizes contextual learning and the development of 21st-century skills, including the 4Cs: critical thinking, creative thinking, collaboration, and communication (Ardiyansyah et al., 2020). Several studies indicate that STEM training can enhance teachers' self-efficacy, enrich learning strategies, and strengthen the relevance of mathematics to real-life contexts; it has even been reported to improve STEM integration skills by up to 82.81% (Bastian et al., 2025). However, research specifically examining how training transforms mathematics teachers' foundational understanding of STEM remains limited. This indicates a research gap, namely a lack of studies focusing on teachers' conceptual changes as the foundation for implementing STEM learning.

Given this gap, this study aims to describe how STEM training transforms the foundational understanding of junior high school mathematics teachers. The focus of this study is on changes in teachers' conceptual understanding as the foundation for effectively implementing STEM learning. This is important because the quality of teachers' foundational understanding significantly influences their ability to design integrated and meaningful learning experiences. Therefore, this study is expected to provide an empirical picture of changes in teachers' understanding following the training and to serve as a reference for the development of more targeted and sustainable training programs.

METHOD

This study adopted a qualitative descriptive design with a *pretest–posttest* approach, in which teachers' responses were analyzed using content analysis to identify patterns of conceptual change rather than to measure learning outcomes quantitatively. The qualitative approach was chosen because it allows researchers to gain a deeper and more contextual understanding of the dynamics of teachers' thinking, as explained by Aspers & Corte (2021) that qualitative research is an iterative process to gain a better understanding of the phenomenon being studied through proximity to the research object. A descriptive design was used because this study did not aim to generalize findings or test the effectiveness of training statistically, but rather to describe in detail the patterns of development and changes in STEM concepts reflected in teachers' essay answers. In the context of educational research, this approach is relevant because it is able to capture the nuances of changes in teachers' understanding comprehensively and contextually, including the process of reflection and reinterpretation of concepts that cannot be revealed through quantitative data alone (Nirwan et al., 2024; Villamin et al., 2024).

This study was conducted as part of an online STEM training program for junior high school mathematics teachers in Bangkalan Regency. The researcher served as the instrument designer, data collector, and data analyst, and was directly involved in the entire research process. To minimize potential bias arising from these roles, several measures were taken to ensure data reliability, including comparing pretest and posttest responses, discussing coding results with peers, and conducting a double-check on the consistency of coding results. This involvement allowed the researcher to gain a deeper understanding of the training context, participant characteristics, and the meaning behind teachers' responses at each stage of instrument completion. This research spanned the entire training series, from the pretest administered before the training to the posttest conducted after all training materials and activities had been completed.

The research subjects consisted of 30 junior high school mathematics teachers selected using purposive sampling. This technique was used because the researcher deliberately selected participants based on certain characteristics considered most relevant and informative for the research objectives (Ahmed, 2024). The criteria used by the researcher for the research subjects were mathematics teachers who participated in STEM training and completed the pretest and posttest instruments. This number of participants was considered adequate in qualitative research because it was able to produce rich, in-depth data that represented the variation in teachers' understanding of STEM concepts in the context of training. Apart from the main subjects, there were no additional informants, because all research data was sourced directly from the written responses of the teachers as the main participants.

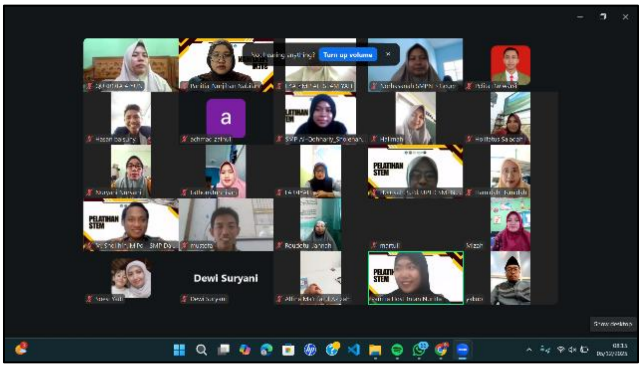


Figure 1. Implementation of the Online STEM Training Program through Zoom Meeting.

Data collection was conducted online using digital forms distributed before and after the training. Evidence of the implementation of online STEM training is presented in Figure 1. In the initial stage, participants were asked to complete a pretest instrument to map teachers' prior knowledge of basic STEM concepts, their understanding of the four components, their experience of implementation, and their perceptions of the differences between STEM learning and conventional learning. The use of open-ended essay questions at this stage was relevant because many STEM learning assessments utilize qualitative instruments to capture changes in knowledge, skills, and affective domains more deeply through the open coding process (Gao et al., 2020). After the training series was completed, participants completed a posttest instrument designed to assess changes in teachers' understanding after receiving the full training. Although the pretest and posttest consisted of different questions, both were developed to measure the same aspects of STEM understanding; therefore, the comparison was conducted not at the item level but through coding teachers' responses using the same categories, enabling the identification of changes in understanding before and after the training. The pretest questions are presented in Table 1, while the posttest questions are presented in Table 2.

Table 1. Pretest Questions

STEM Training Pretest Questions
1. What do you know about the concept of STEM before attending this webinar? Explain in your own words!
2. Of the four components of STEM (Science, Technology, Engineering, Mathematics), which component do you understand best? Why?
3. Have you ever applied STEM-based learning before? If so, give an example. If not, explain why!
4. In your opinion, what is the difference between conventional learning and STEM learning? Explain based on your understanding!
5. If you were asked to explain the basic elements of STEM (S, T, E, M) to students or fellow teachers, how would you explain them?

Table 2. Posttest Questions

STEM Training Posttest Questions
1. How well do you understand the concept of STEM after attending this webinar? How is it different from before the training?
2. Which part of the material helped you understand the basics of STEM most clearly? Explain why!
3. Explain again what Science, Technology, Engineering, and Mathematics are in the context of STEM learning!
4. What is a simple example of STEM application in the classroom that you now understand after the training?
5. How confident are you in explaining the basic concepts of STEM to students or fellow teachers after this webinar? Explain your reasoning!

Data analysis was conducted using content analysis techniques, which included data reduction, coding, categorization, and conclusion drawing. In the data reduction stage, researchers thoroughly read all teacher responses on the pretest and posttest, then filtered out irrelevant answers so that only meaningful information was analyzed further (Monaro et al., 2022). Next, the researcher conducted the coding process by labeling parts of the answers that reflected initial understanding of STEM, changes in concepts, accuracy of understanding, ability to provide examples of application, and the level of teacher confidence after participating in the training, in accordance with the recommendations of open-ended question-based qualitative analysis (Jowsey et al., 2021). The codes were then grouped into thematic categories as a basis for data interpretation.

Although the pretest and posttest instruments consisted of different questions, the analysis did not focus on direct comparisons between questions. Instead, the analysis focused on the interpretation of teachers' answers, which were grouped into thematic categories to represent the development of teachers' conceptual understanding and pedagogical readiness in implementing STEM learning. Based on this analysis process, five main categories were established, namely initial understanding (PA), conceptual change (PK), accuracy of understanding (AP), ability to provide examples of application (CP), and level of confidence (PD). The coding criteria for each category are presented in Table 3.

Table 3. Coding Criteria for Junior High School Teachers' Understanding of STEM Fundamentals

Code	Category	Criteria Description
PA1	Partial understanding	Teachers have limited understanding of STEM and tend to interpret STEM as a general term without clear explanation.
PA2	Misunderstanding	Teachers understand some STEM concepts, but have not demonstrated a complete understanding of the interrelationships between components.
PA3	No understanding	Teachers are unable to explain STEM concepts or state that they do not know STEM.
PK1	Significant improvement	There was a change in understanding from the pretest to the posttest, marked by the interpretation of STEM as an integrated learning approach that connects science, technology, engineering, and mathematics.
PK2	Limited improvement	There was an improvement in understanding, but the integration of the four elements of STEM was not consistent.
PK3	Inconsistent change	Teachers show a change in understanding, but there are still conceptual inconsistencies or inaccuracies in their explanations.
AP1	Minor errors	The definition of STEM still contains conceptual inaccuracies.
AP2	Conceptual errors	The definition is relatively accurate, but there are still minor errors.
AP3	No errors	The definition of STEM is accurate and in accordance with the principles of STEM integration.
CP1	Contextual application	Teachers are able to provide examples of problem-based STEM application that integrates more than one discipline.
CP2	Partial application	Examples only involve one or two STEM elements without clear integration.
CP3	Unable to provide examples	Teachers do not provide examples or examples are not relevant to the STEM approach.
PD1	Low	Teachers are hesitant or state that they are not yet ready to implement STEM in the classroom.
PD2	Moderate	Teachers show initial interest and readiness, but still need guidance.
PD3	High	Teachers state that they are ready and motivated to implement STEM after training.

RESULT AND DISCUSSION

Data analysis was conducted qualitatively through open coding of teachers' essay responses on pre- and post-training instruments. Each response was analyzed by identifying units of meaning, then given initial codes representing initial understanding, conceptual changes, accuracy of STEM understanding, ability to provide examples of application, and teachers' confidence levels. These codes were developed inductively from the data and then grouped into categories to facilitate tracing patterns of change in teachers' understanding and readiness after participating in STEM Pretest and Posttest training. The results of coding teachers' responses based on these categories are presented in detail in Table 4.

Table 4. Coding Matrix for STEM Training Participants

Respondents	Analysis Results of Junior High School Teachers' Answers				
	Initial Understanding (PA)	**Concept Change (PK)**	**Accuracy of Understanding (AP)**	**Examples of Application (CP)**	**Confidence (PD)**
G1	PA1	PK1	AP2	CP1	PD3
G2	PA1	PK1	AP3	CP1	PD3
G3	PA2	PK3	AP1	CP2	PD2
G4	PA3	PK1	AP3	CP1	PD3
G5	PA1	PK2	AP2	CP1	PD3
G6	PA2	PK1	AP3	CP1	PD3
G7	PA3	PK1	AP3	CP1	PD2
G8	PA1	PK3	AP1	CP2	PD3
G9	PA2	PK1	AP3	CP1	PD3
G10	PA1	PK1	AP3	CP1	PD3
G11	PA1	PK1	AP2	CP1	PD3
G12	PA2	PK3	AP1	CP2	PD2
G13	PA3	PK1	AP3	CP1	PD3
G14	PA1	PK2	AP2	CP2	PD2
G15	PA2	PK1	AP3	CP1	PD3
G16	PA3	PK1	AP3	CP1	PD3
G17	PA1	PK3	AP1	CP2	PD2
G18	PA2	PK1	AP3	CP1	PD3
G19	PA2	PK1	AP3	CP1	PD2
G20	PA3	PK1	AP3	CP1	PD3
G21	PA1	PK2	AP2	CP2	PD2
G22	PA2	PK1	AP3	CP1	PD3
G23	PA3	PK1	AP3	CP1	PD3
G24	PA1	PK3	AP1	CP2	PD2
G25	PA2	PK1	AP3	CP1	PD3
G26	PA1	PK1	AP3	CP1	PD3
G27	PA3	PK1	AP3	CP1	PD3
G28	PA1	PK2	AP2	CP2	PD2
G29	PA2	PK1	AP3	CP1	PD3
G30	PA1	PK1	AP3	CP1	PD3

In general, the preliminary results (pre-test) showed that teachers had varying levels of understanding of STEM, ranging from a very general understanding to a fairly accurate understanding. The data indicate that the majority of teachers have shifted toward positive conceptual change (PK1), accompanied by the ability to provide examples of contextual STEM application (CP1) and a high level of self-confidence (PD3), although a small proportion of teachers still fall into the category of partial understanding and application. However, most teachers were unable to explain the concept of STEM in an integrative manner and only mentioned STEM as an integrated learning approach without understanding its characteristics. After the training was provided, the teachers' responses on the posttest showed a significant improvement, both in terms of the accuracy of the definition and the teachers' ability to integrate the four components of STEM into learning. Thus, the training provided a clear picture of how the concept of STEM can be better understood by teachers through material reinforcement activities.

In addition, the data reveal variations in the quality of teachers' explanations based on posttest results. Teachers not only provided longer and more structured answers but also demonstrated a greater conceptual depth. They began to explain the relationships between STEM elements and provided more authentic examples of their application. This indicates that the training encouraged teachers to think more comprehensively and reflectively when implementing STEM in the classroom.

Changes in Teachers' Basic Understanding of STEM

The results of the analysis presented in the Pre-test and Post-test Coding Matrix Table for STEM Training Participants show that before the training was conducted, most teachers were in the partial initial understanding and misconception categories. This finding is in line with the results of the pretest response analysis, which indicates that teachers' initial understanding of STEM is still limited and has not developed conceptually (Dare et al., 2021). Some teachers view STEM only as a form of integrated learning without being able to explain in detail how the process of interdisciplinary integration is realized in learning practices. Many teachers stated that STEM is learning that "combines several subjects," but did not provide an explanation of the objectives of the integration, the stages of implementation, or the pedagogical benefits for students. As a result, the understanding that was formed was still declarative in nature. The results of the analysis of changes in teachers' responses on the pre-test and post-test regarding their understanding of STEM are presented in Figure 2

	Pretest	Posttest
Guru	**Apa yang Anda ketahui tentang konsep STEM sebelum mengikuti webinar ini? Jelaskan dengan kata-kata Anda sendiri.**	**Bagaimana pemahaman Anda tentang konsep STEM setelah mengikuti webinar ini? Apa perbedaannya dibanding sebelum pelatihan?**
G15	STEM adalah pendekatan yang menggabungkan sains, teknologi, teknik, dan matematika untuk memecahkan masalah di dunia nyata.	STEM adalah pendekatan pembelajaran yang berorientasi pada pemecahan masalah, yang melibatkan proses ilmiah, tahapan perancangan teknik, pemanfaatan teknologi, serta penerapan matematika dalam kegiatan pembelajaran terpadu.
G19	STEM adalah pendekatan yang mengintegrasikan sains, teknologi, teknik, dan matematika untuk memecahkan masalah di dunia nyata serta mendorong pemikiran kritis, kreativitas, dan kerja sama.	Sebelum pelatihan, STEM hanya dipahami sebagai singkatan dari empat bidang ilmu. Setelah pelatihan, STEM dipahami sebagai pendekatan pendidikan yang berfokus pada pengembangan keterampilan pemecahan masalah, pemikiran kritis, dan inovasi siswa.

Figure 2. Results of the Analysis of Changes In Teachers' Responses Regarding Their Understanding of STEM.

The limitations in explaining the objectives, processes, and benefits of STEM integration indicate that teachers' familiarity with the term "STEM" has not been accompanied by a comprehensive understanding of the characteristics and principles of interdisciplinary integration that form the essence of this approach. This finding is in line with research results that reveal that teachers still have a less than holistic understanding of the STEM concept and tend to only be able to relate science and mathematics, while the elements of technology and engineering are not yet clearly understood, resulting in limited STEM learning integration (Jamaluddin et al., 2023). This is also evident in the fact that many science, technology, and mathematics teachers still view STEM as a "collection" of separate subjects rather than an interdisciplinary approach, meaning that few are truly capable of integrating various disciplines to solve real-world problems (Huang et al., 2022). Thus, limited pedagogical experience and minimal exposure to integrated learning prior to participating in training can be seen as factors contributing to teachers' low initial understanding of STEM. Examples of teachers' pretest and posttest responses are presented in Table 5 as follows.

Table 5. Examples of Changes in Teachers' Understanding of STEM Based on Pretest and Posttest Responses

Teacher	Pretest Response (Before Training)	Posttest Response (After Training)	Interpretation of Change
G15	STEM is an approach that combines science, technology, engineering, and mathematics to solve real-world problems.	STEM is a problem-solving–oriented learning approach that involves scientific processes, engineering design stages, the use of technology, and mathematical applications in an integrated learning activity.	The teacher's initial understanding falls into the **Misunderstanding Category (PA2)**, as STEM was described as a general integration without explaining the interrelationships between components; after the training, the understanding developed into a more comprehensive and integrated conception.
G19	STEM is an approach that integrates science, technology, engineering, and mathematics to solve real-world problems and promotes critical thinking, creativity, and collaboration.	Before the training, STEM was understood only as an acronym of four disciplines. After the training, it is understood as an educational approach that focuses on developing students' problem-solving skills, critical thinking, and innovation.	The teacher's initial understanding falls into the **Misunderstanding Category (PA2)**, as STEM was described generally without clear explanation of the interrelationships between its components; after the training, the understanding improved toward a more meaningful and application-oriented conception.

After the training was conducted, there was a significant change in the quality of teachers' understanding, as reflected in their more systematic and structured post-test answers. Teachers began to understand STEM not merely as an acronym for four fields of science, but as a learning approach that emphasizes problem solving. In addition, teachers also began to realize that STEM learning requires the integration of scientific processes, the use of technology, engineering design, and the application of mathematical concepts in a series of learning activities. The findings, as shown in Table 5, indicate that teachers' understanding shifted from viewing STEM as a general integration of disciplines to a more developed conception of STEM as a problem-solving–oriented and interdisciplinary approach that emphasizes critical thinking, innovation, and integrated learning processes. This condition is reinforced by previous research findings which state that STEM-based training aims to improve teachers' knowledge and practice in the context of authentic learning, although effective professional development strategies are still needed to facilitate more substantial changes in understanding (Zhou et al., 2023). This pattern shows that teachers are beginning to view STEM as a pedagogical framework that emphasizes thinking processes and problem-solving strategies, rather than simply as a combination of cross-disciplinary materials (Dare et al., 2021).

Changes in teachers' understanding patterns after training indicate a clear conceptual shift compared to the initial conditions before the training was provided. These changes in understanding are in line with findings showing that training has a strong positive effect on increasing STEM teachers' self-efficacy, which is an indicator of teachers' readiness and confidence in implementing new pedagogical concepts in their learning contexts (Boz, 2023). This reinforces the argument that the development of comprehensive and structured training materials can accelerate the transformation of teachers' conceptual knowledge from partial understanding to more integrative understanding. However, a small number of teachers still fall into the limited improvement and inconsistent categories, indicating that the internalization of STEM concepts is a gradual process that requires ongoing guidance and continuous practical experience.

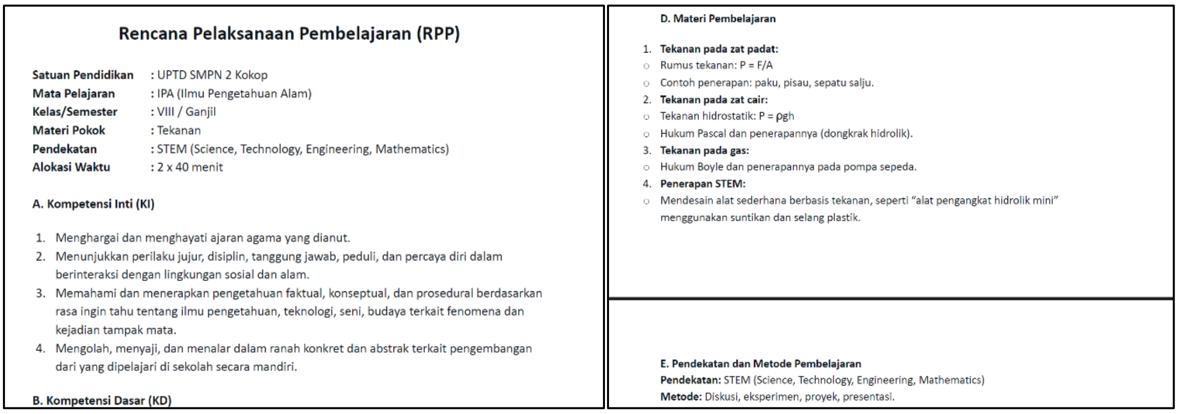
Teachers' Development in Providing Examples of STEM Application

The aspect of teachers' ability to provide examples of STEM application, which was analyzed using the Pre-test and Post-test Coding Matrix Table for STEM Training Participants, showed a clear difference between the conditions before and after the training. The pre-test analysis results showed that most teachers still had difficulty formulating learning examples that truly reflected the integration of science, technology, engineering, and mathematics as a whole. In line with Liu et al (2025), who highlight that a major challenge in STEM implementation is teachers' difficulty in translating STEM concepts into classroom practice, the examples of STEM application provided tended to be limited to one or two fields of science, such as simple science experiments, without involving the engineering design process or the use of technology. This condition shows that teachers in the early stages did not yet have a comprehensive picture of the characteristics of STEM learning based on contextual problem solving and interdisciplinary integration. Therefore, professional development that emphasizes reflection and authentic learning practices is needed so that teachers are able to provide more contextual and integrated examples of STEM application. Examples of teachers' responses regarding the implementation of STEM based on posttest results are presented in Table 6 as follows.

Table 6. Examples of Teachers' Ability in Providing STEM Application

Teacher	Example of STEM Application	Interpretation
G5	Students create a bridge model using ice cream sticks. They learn about force and material strength (Science), use simple tools (Technology), design a strong structure (Engineering), and measure dimensions and calculate load capacity (Mathematics).	The teacher demonstrates **Contextual Application (CP1)** by providing a problem-based activity that clearly integrates all STEM components in a structured and meaningful way.
G19	Students create a bridge model using simple materials such as ice cream sticks and glue. They apply science concepts to understand strength and stability, use tools (Technology), design structures (Engineering), and measure dimensions (Mathematics).	The teacher demonstrates **Contextual Application (CP1)** by integrating multiple STEM components within a relevant and problem-based learning activity.

After the training was conducted, there was a significant improvement in the quality of STEM application examples provided by teachers, as reflected in the posttest results summarized in the Pre-test and Post-test Coding Matrix Table for STEM Training Participants. The majority of teachers were in the contextual application category, which is characterized by the ability to relate STEM concepts to relevant and authentic learning situations (Hallström et al., 2023). Teachers provided examples of activities involving real-world problem solving, such as waste reduction projects, simple model construction, and experiments that include the process of designing solutions. In addition, the integration of technology and the use of mathematical calculations were evident in the examples provided, indicating that teachers were able to incorporate STEM components in a more comprehensive and integrated manner. To illustrate teachers’ ability to incorporate STEM concepts into lesson planning, an example of a STEM lesson plan developed by a teacher is presented in Figure 3.



Rencana Pelaksanaan Pembelajaran (RPP)

Satuan Pendidikan : UPTD SMPN 2 Kokop
Mata Pelajaran : IPA (Ilmu Pengetahuan Alam)
Kelas/Semester : VIII / Ganjil
Materi Pokok : Tekanan
Pendekatan : STEM (Science, Technology, Engineering, Mathematics)
Alokasi Waktu : 2 x 40 menit

A. Kompetensi Inti (KI)

1. Menghargai dan menghayati ajaran agama yang dianut.
2. Menunjukkan perilaku jujur, disiplin, tanggung jawab, peduli, dan percaya diri dalam berinteraksi dengan lingkungan sosial dan alam.
3. Memahami dan menerapkan pengetahuan faktual, konseptual, dan prosedural berdasarkan rasa ingin tahu tentang ilmu pengetahuan, teknologi, seni, budaya terkait fenomena dan kejadian tampak mata.
4. Mengolah, menyaji, dan menalar dalam ranah konkret dan abstrak terkait pengembangan dari yang dipelajari di sekolah secara mandiri.

B. Kompetensi Dasar (KD)

D. Materi Pembelajaran

1. **Tekanan pada zat padat:**
   - Rumus tekanan: $P = F/A$
   - Contoh penerapan: paku, pisau, sepatu salju.
2. **Tekanan pada zat cair:**
   - Tekanan hidrostatik: $P = \rho gh$
   - Hukum Pascal dan penerapannya (dongkrak hidrolik).
3. **Tekanan pada gas:**
   - Hukum Boyle dan penerapannya pada pompa sepeda.
4. **Penerapan STEM:**
   - Mendesain alat sederhana berbasis tekanan, seperti “alat pengangkat hidrolik mini” menggunakan suntikan dan selang plastik.

E. Pendekatan dan Metode Pembelajaran
Pendekatan: STEM (Science, Technology, Engineering, Mathematics)
Metode: Diskusi, eksperimen, proyek, presentasi.

Figure 3. Examples of STEM Lesson Plans Developed by Teachers After Completing the Training

The changes in the quality of these examples indicate an increase in teachers' applied understanding of STEM learning. Based on the discussion activities presented in Figure 4, it was found that teachers no longer view STEM merely as a theoretical concept, but rather as a project-based learning approach focused on contextual problem-solving teachers no longer view STEM as merely a theoretical concept, but rather as a project-oriented learning approach focused on contextual problem solving. However, there are still a small number of teachers in the partial implementation category, indicating that interdisciplinary integration is not yet fully optimal and still needs to be strengthened. These findings reinforce the results of other studies which state that teachers' applied skills in STEM learning develop gradually through continuous training and collaborative learning, where teachers are encouraged to consistently design and practice interdisciplinary teaching strategies (Zuhaida et al., 2025). Therefore, improving the quality of STEM implementation examples can be seen as an important indicator of training success, while also confirming that continued support is still needed to ensure effective and sustainable STEM implementation in the classroom.

Figure 4. Discussion Session for STEM Training Participants

Increased Teacher Confidence in Implementing STEM

The coding results on the aspect of teacher confidence presented in the Pre-test and Post-test Coding Matrix Table for STEM Training Participants show a clear difference between the conditions before and after training. At the pre-test stage, the level of teacher confidence in explaining and implementing STEM was still low to moderate. Some teachers stated that they did not yet fully understand the concept of STEM, so they felt unable to explain the material to students and expressed doubts because they had never directly applied STEM-based learning. This condition indicates that limited conceptual understanding and minimal practical experience have a direct influence on teachers' low confidence in applying innovative learning in the classroom. Similar conditions have also been reported among teachers and prospective teachers in various contexts, where a lack of experience and exposure to integrated STEM learning has caused them to feel unprepared and less confident in teaching it (Martínez-Borreguero et al., 2022). Examples of teachers' responses regarding their level of confidence in explaining STEM concepts, based on the posttest results, are presented in Table 7 as follows.

Table 7. Teachers' Confidence in Explaining STEM Concepts

Teacher	Response	Interpretation
G5	I feel quite confident after participating in this webinar. The material was well-structured and provided concrete examples, giving me a clear understanding of the concepts, benefits, and implementation of STEM. I also gained an understanding of how to design simple yet meaningful learning activities, so I am ready to explain them to students and fellow teachers.	The teacher demonstrates **High Confidence (PD3)**, supported by clear reasoning, structured understanding, and readiness to apply and explain STEM concepts in practice.
G19	Confident because I already know the steps of STEM.	The teacher demonstrates **Moderate Confidence (PD2)**, as the response shows basic understanding but lacks detailed explanation or strong justification of readiness.

After participating in the training, most teachers showed significant improvement and were categorized as having high confidence, as reflected in the posttest results in the Pre-test and Post-test Coding Matrix Table for STEM Training Participants. Teachers expressed greater readiness and confidence to explain and apply the STEM approach in real learning contexts. These findings are consistent with the research by Berisha & Vula (2021), which shows that after participating in STEM workshops or courses, pre-service teachers experience increased confidence in implementing STEM instruction and are motivated to seek out various examples of practices from other countries to enrich their understanding. This improvement occurred because teachers obtained more detailed explanations, concrete examples of implementation, and an overview of the steps for integrating STEM into learning, so that they felt more confident to try it in the classroom. This change indicates that the training not only contributed to conceptual understanding but also strengthened teachers' psychological readiness to innovate in learning. These findings are in line with research results stating that comprehensively designed STEM professional training can increase teachers' self-efficacy in implementing STEM learning, making teachers more confident and ready to make real pedagogical changes (Kelley et al., 2020).

However, the analysis also shows that a small number of teachers still fall into the moderate confidence category after the training. This condition indicates that increased confidence does not always occur evenly and instantly among all participants. Recent literature confirms that strengthening teachers' confidence in STEM learning is generally influenced by continuous professional learning experiences, involving hands-on practice, reflective discussions, and consistent collegial support (Boz, 2023). This finding is reinforced by reports from long-term professional development programs that show a significant increase in “STEM teacher efficacy self-ratings,” in which teachers and principals report that teachers have become “more confident” and “more comfortable” after participating in a series of workshops and ongoing classroom mentoring (Dwyer et al., 2023). Overall, the increase in teacher confidence is a very important finding in the context of STEM learning implementation. Teachers who have conceptual understanding but lack confidence tend to be reluctant to apply new learning approaches in the classroom. The research data shows that the training successfully increased teachers' confidence to explain and implement STEM more optimally. Thus, teacher confidence can be viewed as crucial psychopedagogical capital for the successful implementation of STEM in schools, while also emphasizing the importance of training that is designed to be sustainable and oriented towards practical application.

CONCLUSION AND SUGGESTIONS

Basic STEM training has a positive impact on mathematics teachers’ understanding, shifting it from partial and misconception-based views toward a more accurate and integrative conception of STEM as an interdisciplinary, problem-solving–oriented approach. In addition, the training enhances teachers’ ability to provide contextual and authentic examples of STEM application, as well as their confidence in implementing STEM-based learning in the classroom. However, the presence of a small number of teachers who show limited improvement indicates that the internalization of STEM concepts requires a gradual process and sustained support.

In addition to enhancing conceptual understanding, STEM training also contributes to strengthening teachers' applied skills and affective aspects. Teachers demonstrated improved ability to present contextual and authentic STEM learning examples and connect them to real-life problems. The internalization of STEM concepts is a gradual process that requires ongoing support. Therefore, further research is recommended to examine the long-term impact of this training through ongoing mentoring and direct classroom observation. Additionally, contextual factors such as school support and teacher collaboration also need to be investigated, as both play a crucial role in the successful and sustainable implementation of STEM education.

REFERENCES

Ahmed, S. K. (2024). How to choose a sampling technique and determine sample size for research : A simplified guide for researchers Sirwan Khalid Ahmed To cite this version : HAL Id : hal-04718988. *Oral Oncology Reports*, *12*, 100662. https://doi.org/10.1016/j.oor.2024.100662

AlAli, R. (2024). Enhancing 21ST Century Skills Through Integrated STEM Education Using Project-Oriented Problem-Based Learning. *Geojournal of Tourism and Geosites ISSN*, *53*(2), 421–430. https://doi.org/10.30892/gtg.53205-1217

Ardiyansyah, R., Diella, D., & Suhendi, H. Y. (2020). *Pelatihan Pengembangan Perangkat Pembelajaran Abad 21 Dengan Model Pembelajaran Project Based Learning Berbasis STEM Bagi Guru IPA*. *10*, 31–36.

Aspers, P., & Corte, U. (2021). What is Qualitative in Research. *Qualitative Sociology*, 599–608. https://doi.org/10.1007/s11133-021-09497-w

Bastian, A., Sari, E., Awal, R., Whayuni, S., & Chahyadi, E. (2025). STEM Integration Training in Learning for Teachers of SMK Kesehatan Proskill Indonesia Pekanbaru and Tualang. *DINAMISIA: Jurnal Pengabdian Kepada Masyarakat*, *9*(3), 949–958.

Berisha, F., & Vula, E. (2021). Developing Pre-service Teachers Conceptualization of STEM and STEM Pedagogical Practices. *Frontiers in Education*, *6*, 1–10. https://doi.org/10.3389/feduc.2021.585075

Boz, T. (2023). Teacher Professional Development for STEM Integration in Elementary / Primary Schools : A Systematic Review. *International Electronic Journal of Elementary Education*, *15*(5), 371–382.

Dare, E. A., Keratithamkul, K., & Hiwatig, B. M. (2021). Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Education Sciences*, 1–22.

Dwita, L., & Susanah. (2020). Penerapan Pendekatan Science, Technology, Engineering, and Mathematics (STEM) dalam Pembelajaran Matematika di SMK pada Jurusan Bisnis Konstruksi dan Properti. *MATHEdunesa Jurnal Ilmiah Pendidikan Matematika*, *9*(2), 276–285.

Dwyer, A. O., Hourigan, M., Leavy, A. M., & Corry, E. (2023). ' I Have Seen STEM in Action and It ' s Quite Do - able !' The Impact of an Extended Professional Development Model on Teacher Efficacy in Primary STEM Education. *International Journal of Science and Mathematics Education*, *21*, 131–157. https://doi.org/10.1007/s10763-023-10361-2

Ferdiansyah, F., Noer, S. H., & Widyantuti. (2025). Enhancing Secondary Students' Mathematical Creative Thinking Trough STEM Project-Based Learning. *Kalamatika: Jurnal Pendidikan Matematika*, *10*(1), 47–66.

Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *International Journal of STEM Education*, *4*, 1–14.

Hallström, J., Norström, P., & Schönborn, K. J. (2023). Authentic STEM education through modelling : an international Delphi study. *International Journal of STEM Education*, 1–16. https://doi.org/10.1186/s40594-

023-00453-4

Huang, X., Erduran, S., Zhang, P., Luo, K., & Li, C. (2022). Enhancing teachers ' STEM understanding through observation , discussion and reflection. *Journal of Education for Teaching*, *48*(5), 576–591. https://doi.org/10.1080/02607476.2021.2006571

Jamaluddin, R., Haslinda, N., Shah, M., Hazwan, M., Puad, M., & Mohd, E. K. (2023). The Integration of Science Technology Engineering and Mathematics (STEM) in Home Science : Teachers ' Understanding and Challenges. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *2*(2), 42–50.

Jowsey, T., Deng, C., & Weller, J. (2021). General-purpose thematic analysis : a useful qualitative method for anaesthesia research. *BJA Education*, *21*(12), 472–478. https://doi.org/10.1016/j.bjae.2021.07.006

Kelley, T. R., Knowles, J. G., Holland, J. D., & Han, J. (2020). Increasing high school teachers self-efficacy for integrated STEM instruction through a collaborative community of practice. *International Journal of STEM Education*, 1–13.

Kong, S. F., & Matore, M. E. E. M. (2022). Can a Science , Technology , Engineering , and Mathematics (STEM) Approach Enhance Students ' Mathematics Performance ? *Sustaunability*, *14*(379).

Kusmaryono, I., Aminudin, M., Ubaidah, N., & Chamalah, E. (2024). The Bridging Understanding of Language and Mathematical Symbols Betweeen Teachers and Students: An Effort to Increase Mathematical Literacy. *Journal of Mathematics Education*, *13*(1), 251–270.

Liu, J., Wang, K., & Pan, Z. (2025). *The Effectiveness of Professional Development in the Self-Efficacy of In-Service Teachers in STEM Education :* 1–24.

Martínez-Borreguero, G., Naranjo-Correa, F. L., & Mateos-Núñez, M. (2022). Cognitive and Emotional Development of STEM Skills in Primary School Teacher Training through Practical Work. *Education Sciences*, 1–21.

Monaro, S., Gullick, J., & West, S. (2022). *Qualitative Data Analysis for Health Research : A Step-by-Step Example of Phenomenological Interpretation Qualitative Data Analysis for Health Research : A Step-by-Step Example of*. *27*(4), 1040–1057.

Mubarik, Permata, D., Pathuddin, Anggraini, Nasir, R., Alfisyahra, Meinarni, W., Fajriani, Desti, Rumi, M. F., Ulfiana, D., & Muazin, M. (2022). Analysis of the Application of STEM Approaches in Mathematics Learning in Junior High Schools. *Journal of Mathematics Education*, *7*(2), 108–114.

Nirwan, Faudi, Isra, R., & AG, B. (2024). Qualitative Descriptive Research: Integrating Inquiry-Based Learning Into Elementary School English Instruction. *Getsempena English Education Journal (GEEJ)*, *11*(1), 1–15.

OECD. (2023). Pisa 2022 Results. In *Factsheets: Vol. I*. https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_53f23881-en%0Ahttps://www.oecd.org/publication/pisa-2022-results/country-notes/germany-1a2cf137/

Rahmawati, T. D., & Ndori, V. H. (2022). *Implementation of Mathematics Learning With A STEM Approach (Science , Technology , Engineering , And Mathematics) at MTs Muhammadiyah Wuring Implementasi Pembelajaran Matematika dengan Pendekatan STEM (Science , Technologi , Engineering , And Mathematics) di Mts Muhammadiyah Wuring*. *7*, 330–341.

Saputri, V., & Herman, T. (2022). Integrasi STEM dalam Pembelajaran Matematika: Dampak Terhadap Kompetensi Matematika Abad 21. *Jurnal Pembelajaran Matematika Inovatif*, *5*(1), 247–260. https://doi.org/10.22460/jpmi.v5i1.247-260

Sari, F. A., & Juandi, D. (2021). Mathematics Teachers' Perception About STEM-Based Learning. *Prima: Jurnal Pendidikan Matematika*, *5*(1), 23–34.

Villamin, P., Lopez, V., Thapa, D. K., & Cleary, M. (2024). A Worked Example of Qualitative Descriptive Design : A Step Guide for Novice and Early Career Researchers. *Journal of Advanced Nursing*, 5181–5195. https://doi.org/10.1111/jan.16481

Zhou, X., Shu, L., Xu, Z., & Padrón, Y. (2023). The effect of professional development on in - service STEM teachers ' self - efficacy : a meta - analysis of experimental studies. *International Journal of STEM Education*, 1–20. https://doi.org/10.1186/s40594-023-00422-x

Zuhaida, A., Widodo, A., Prima, E. C., & Solihat, R. (2025). *STEM professional development : A decade of progress*. *22*(1), 1–17.