



DOI: doi.org/10.58797/teras.0401.06

Empowering Science Teachers through STEM-Based Teaching Module Development Training

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Received: December 22, 2024

Revised: June 27, 2025

Accepted: June 29, 2025

Published: June 30, 2025

Issued: June 30, 2025

**Mitra Teras: Jurnal Terapan
Pengabdian Masyarakat**

p-ISSN: 2963-2102

e-ISSN: 2964-6367



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Abstract

This article presents a program that supports science teachers in improving their professional competence through structured training focused on developing STEM-based teaching modules. The program emphasized the importance of integrating Science, Technology, Engineering, and Mathematics (STEM) into lesson plans to strengthen students' problem-solving, creativity, collaboration, and critical thinking. The main components of the module were problem formulation, inquiry planning, experimentation or engineering design, data analysis, and reflection. Teachers were guided to set learning objectives aligned with STEM principles, develop authentic assessment instruments, and apply interdisciplinary teaching methods. The training results showed that teachers became more capable of designing relevant and engaging learning experiences. This program highlights the importance of equipping teachers with the tools they need to deliver STEM instruction that meets the needs of 21st-century students.

Keywords: STEM education, science teachers, module development, teacher training

INTRODUCTION

Challenges in education, especially in science, have led many teachers to adapt to the development of educational technologies and evolving instructional models. Students need learning methods that help them understand subject matter in a more practical and efficient way. Many students are already adept at using technologies such as smartphones, tablets, and computers, which creates a growing demand for learning materials that can be accessed anytime and anywhere. Technological advancements have enabled the emergence of various platforms that students can use to access a wide range of learning content, particularly in science education (Sofi-Karim et al., 2022; Timotheou et al., 2022). Science is the study of nature and the world around us. Learning science solely through textbooks has proven insufficient to help students fully grasp scientific concepts (Siantuba et al., 2023). With significant technological progress, students now feel more comfortable and engaged when learning is supported by technology (Wen et al., 2023).

To meet the challenges of 21st-century learning, an instructional approach that enhances students' critical thinking skills is essential (Haug & Mork, 2021). In this context, students do not necessarily require constant supervision to learn something new or understand certain materials. Instead, they need learning media that can be used independently in their daily learning activities. Currently, many schools still rely on traditional teaching methods in which the teacher acts as the central figure in the learning process. In such teacher-centered environments, the flow and direction of learning are fully determined by the teacher. This often limits students' autonomy and slows their progress in understanding learning materials. One approach that can address these challenges is the STEM approach (Conde et al., 2020). STEM stands for Science, Technology, Engineering, and Mathematics, and it integrates these disciplines into a cohesive learning model. This integration makes STEM a promising approach for developing students' critical thinking skills. However, implementing the STEM approach comes with its own challenges for teachers and educators (Margot & Kettler, 2019), including limited understanding of STEM-based instruction and a lack of resources or personnel with sufficient competence to implement STEM learning effectively in the classroom.

This highlights the importance of training and developing the competencies of teachers and educators. In developing STEM-related skills, teachers may feel that certain subjects are less relevant to the disciplinary components of STEM (Şat & Çağıltay, 2024). At times, they also face difficulties in integrating learning content with the STEM approach. These limitations can be addressed, in part, by supporting teachers in developing the necessary competencies. The competencies required to implement the STEM approach in the classroom include pedagogical knowledge related to the STEM curriculum, the ability to apply inquiry- and project-based learning, 21st-century skills, and digital literacy (Zhao et al., 2021). In facing the challenges of the 21st century, teachers are required to adapt to rapid technological advancement. One such demand is the ability to develop teaching materials that are integrated with technology. Teaching materials come in various forms, such as student worksheets, e-modules, PowerPoint presentations, interactive simulations, and websites (Schmidthaler et al.,

2023). Developing technology-integrated teaching materials requires strong digital literacy skills. Therefore, training is needed to improve teachers' digital literacy (Polatuly et al., 2024) so that they can effectively create technology-enhanced instructional resources.

DEFINITION OF THE STEM APPROACH

The STEM learning approach integrates four disciplines: science, technology, engineering, and mathematics. STEM can be incorporated into a single conceptual learning experience. The STEM approach continues to evolve in response to the changing needs of the education sector, in which students are expected not only to understand theoretical concepts but also to apply them in real life to solve complex problems. STEM helps students develop critical and creative thinking, the ability to collaborate in teams, and the capacity to communicate ideas effectively and creatively. The application of the STEM approach is essential in education, especially in science education, because science is inherently linked to technological advancement, engineering application, and mathematical analysis.

Through the STEM approach, science learning becomes more meaningful because it is oriented toward real-world practice and contextual problem-solving. In STEM-based learning, the focus is no longer on memorizing concepts but on developing higher-order thinking and problem-solving skills (Jeon et al., 2021). Currently, schools in Indonesia are implementing the *Merdeka* Curriculum, which gives teachers and students greater flexibility to explore project-based learning approaches that are aligned with the values of STEM. With this approach, students are expected to actively construct knowledge based on hands-on experience and exploration of real-world issues around them (Li et al., 2025). Therefore, the integration of STEM into science education is not merely a global trend but a strategic necessity to prepare students for 21st-century challenges (Han et al., 2021).

TEACHING MODULE: DEFINITION AND KEY ELEMENTS

In Indonesia's current education system, the teaching module is one of the key components supporting the implementation of the school curriculum. A teaching module is defined as a learning tool that contains a complete and systematic lesson plan (Keenahan & McCrum, 2020). It is developed by teachers or educators to facilitate a structured, measurable, and learning-outcome-oriented process. Teaching modules give teachers flexibility to adapt content, methods, and learning strategies to students' needs. Structurally, a teaching module consists of several essential elements: (1) module identity, which includes the author's name, grade level, time allocation, and subject; (2) targeted competencies, which consist of learning outcomes (CP), learning objectives (TP), and the flow of learning objectives (ATP); (3) the learning model used, such as project-based learning, STEM, or problem-based learning; (4) assessment, including formative and summative assessment; (5) learning steps or activities; (6) media, tools, and learning resources; and (7) enrichment and remedial materials to address varying levels of student achievement.

The *Merdeka* Curriculum emphasizes the principles of flexibility, relevance, and differentiation in learning. Teaching modules serve as a medium for teachers to translate these

principles into classroom practice. By designing teaching modules independently, teachers can tailor the content to the specific learning needs of their students. Moreover, the development of teaching modules also supports the realization of the Pancasila Student Profile, which describes students who are faithful, independent, critical, creative, collaborative, and open to global diversity. Therefore, teachers' ability to design teaching modules aligned with the STEM approach is crucial for fostering transformative and contextual learning experiences (Ramadannisa et al., 2025).

STRENGTHENING TEACHERS' COMPETENCE THROUGH MODULE DEVELOPMENT TRAINING

Teacher training is a strategic process for enhancing educators' professionalism, enabling them to fulfill their roles optimally amid the ever-evolving demands of education. In the context of implementing the *Merdeka* Curriculum and the STEM approach, teacher training involves not only the improvement of pedagogical and content knowledge but also the development of innovative skills in designing instructional tools and creating meaningful learning experiences. Such training can be conducted through workshops or ongoing professional development programs (Ramos et al., 2021). Training serves as a form of scaffolding that helps teachers develop competencies that were previously beyond their reach. It provides support and guidance in the form of materials, facilitation, and hands-on practice, allowing teachers to enhance their skills gradually.

According to Kolb's experiential learning theory, effective learning occurs through concrete experience, reflection, abstract conceptualization, and experimentation, an approach highly suitable for training in instructional material development (Kolb & Kolb, 2005). Furthermore, Guskey (2002) proposed a model of professional development which emphasizes that changes in teaching practice are unlikely unless teachers perceive tangible benefits from the training, such as improved understanding, greater teaching effectiveness, and better student learning outcomes. Therefore, training on developing STEM-based teaching modules must be designed with a focus on active teacher engagement, deep reflection, and the reinforcement of belief in the effectiveness of the STEM approach. Quality training goes beyond simply delivering knowledge; it should also foster collaborative spaces among teachers, build learning communities, and cultivate a culture of innovation and creativity. In this way, strengthening teachers' competence through STEM-based module development training becomes a strategic step toward improving the quality of education so that it is relevant, contextual, and future-oriented.

A primary emphasis of educational advancement is improving teachers' expertise, particularly in implementing innovative and effective teaching methods. Training in the development of instructional modules is a theoretically grounded approach to capacity building. This approach originates from the idea that educators facilitate meaningful learning experiences in addition to transmitting knowledge. Through such training, educators become familiar with pedagogical frameworks that emphasize inquiry-based learning, student-centered approaches, and lesson design that integrates real-world situations. The development of instructional

modules puts theoretical instructional frameworks into practice. STEM-based module design aligns with constructivist learning theory, which asserts that students gain knowledge through active involvement. Educators who undergo module development training become more proficient in internalizing essential educational principles, such as the alignment of learning objectives, instructional methods, and assessment. Moreover, such training fosters self-sufficiency and reflective practice, both of which are essential for professional teaching competence. From a theoretical perspective, creating a teaching module enhances educators' understanding of curricular content, instructional design, and learner needs, while also functioning as a cognitive and pedagogical exercise. By positioning educators as curriculum makers who integrate diverse educational ideas into practice, it fosters the professionalization of teaching. Consequently, enhancing teacher competence through module development training serves as both a theoretical and a practical means of strengthening the teacher's role as a learning architect.

CONCLUSION

The integration of the STEM approach into education, especially in the development of teaching materials, has become a necessity in facing technological advancements in education. The STEM approach, which encompasses four disciplines, can be used to enhance students' critical thinking and problem-solving skills. However, one challenge frequently encountered today is teachers' limited ability to develop technology-based teaching materials, including teaching modules that implement the STEM approach in learning activities. Such modules must be well structured and meet the criteria of a teaching module based on a particular learning approach. Therefore, to create modules that integrate the STEM approach, training is needed to enhance teachers' competence in developing technology-based materials. The training must support teachers in understanding the theoretical framework, designing integrative learning activities, and reflecting on those activities.

STATEMENTS AND DECLARATIONS

Acknowledgments. The authors thank the science teachers who participated in the training for their cooperation and active participation throughout the program.

Funding. This community service activity was funded by Community Service Grant Number 46/SPK-PKM/FMIPA/2023 and the Decree of the Rector of Universitas Negeri Jakarta Number 434/UN39/HK.02/2024.

Conflict of Interest. The authors declare no conflict of interest.

Author Contributions. All authors contributed to program design, implementation, data collection and analysis, and writing and editing of the manuscript. All authors read and approved the final manuscript.

Use of AI. The authors did not use generative AI in preparing this manuscript, Grammarly used for enhance the readability. The authors reviewed the entire content and take full responsibility for it.

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