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Empowering Science Teachers through STEM-Based Teaching Module Development Training

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Abstract

This article presents a program that helps science teachers get better at their jobs by giving them structured training that focuses on creating STEM-based lesson plans. The program stressed the importance of including Science, Technology, Engineering, and Mathematics (STEM) in lesson plans to help students become better at problem-solving, being creative, working together, and thinking critically. The main parts of the module were coming up with problems, planning inquiries, doing experiments or designing engineering projects, analyzing data, and thinking about what happened. Teachers were told to set learning goals that were in line with STEM principles, create real-world assessment tools, and use methods that crossed subject areas in their teaching. The training results showed that teachers were better at making learning experiences that were relevant and interesting. This project shows how important it is to give teachers the tools they need to teach STEM classes in a way that meets the needs of 21st-century students.

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

INTRODUCTION

Challenges in the field of education, especially in science, have led many teachers to adapt to the development of educational technologies and evolving instructional models. Students require 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. This creates a growing demand for learning materials that are easily accessible 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. Science is the study of nature and the world around us. So far, learning science solely through textbooks has proven insufficient to help students fully grasp scientific concepts. With significant technological progress, students now feel more comfortable and engaged when learning is supported by the use of technology.

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 where 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 as the facilitator. This often limits students' autonomy and slows down 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 integrates these disciplines into a cohesive learning model. The integration of these fields makes STEM a promising approach for developing students' critical thinking skills. However, implementing the STEM approach comes with its own set of challenges for teachers and educators (Frederic Jr. et al., 2024). These include limited understanding of STEM-based instruction and a lack of resources or personnel with sufficient competence to effectively implement STEM learning in the classroom.

This highlights the importance of training and developing the skills and competencies of teachers or educators. In developing STEM-related skills, teachers may sometimes feel that certain subjects are less relevant to the disciplinary components of STEM (Sat & Cagiltay, 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 21st-century skills, teachers are required to adapt to the rapid advancement of technology. 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, websites, and others. To develop technology-integrated teaching materials, strong digital literacy skills are essential. Therefore, training is needed to improve teachers' digital literacy capabilities (Polatuly et al., 2024) so they can effectively create technology-enhanced instructional resources.

DEFINITION OF STEM APPROACH

The STEM learning approach is an approach that 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 ever-changing needs of the education sector, where students are not only expected to understand theoretical concepts but also to apply them in real life to solve complex problems. STEM facilitates students in developing 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 it is inherently linked to technological advancement, engineering application, and mathematical analysis.

Through the STEM approach, science learning becomes more meaningful as it is oriented toward real-world practice and contextual problem-solving processes. In STEM-based learning, the focus is no longer on memorizing concepts, but rather on developing higher-order thinking skills and problem-solving abilities (Jeon et al., 2021). Currently, schools in Indonesia are implementing the Merdeka Curriculum, which provides greater flexibility for both teachers and students to explore project-based learning approaches that are also 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 in science education is not merely a global trend but a strategic necessity to prepare students to face 21st-century challenges (Han et al., 2021).

TEACHING MODULE: DEFINITION, KEY ELEMENTS

In Indonesia's current education system, the teaching module is one of the key components that supports 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 provide flexibility for teachers to adapt the content, methods, and learning strategies to meet students' needs. Structurally, a teaching module consists of several essential elements, including: (1) Module identity, which includes the name of the author, grade level, time allocation, and subject name; (2) Targeted competencies, which consist of learning outcomes (CP), learning objectives (TP), and the learning objectives flow (ATP); (3) Learning model used, such as project-based learning, STEM, or problem-based learning models; (4) Assessment, including both formative and summative types; (5) Learning steps or activities; (6) Media, tools, and learning resources; and (7) Enrichment and remedial materials to address the varying levels of student achievement.

In the context of the Merdeka Curriculum, this 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 independently designing teaching modules, teachers can tailor the content to the specific learning needs of their students. Moreover, the development of teaching modules is also aimed at supporting the realization of the Pancasila Student Profile, students who are faithful, independent, critical thinkers, creative, collaborative, and globally diverse. Therefore, teachers' ability to design teaching modules aligned with the STEM approach is crucial for fostering transformative and contextual learning experiences.

STRENGTHENING TEACHERS' COMPETENCE THROUGH TRAINING MODULE DEVELOPMENT

Teacher training is a strategic process in enhancing educators' professionalism, enabling them to fulfill their roles optimally amidst 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. 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 gradually enhance their skills.

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. Furthermore, Guskey (2002) proposed a model of professional development which emphasizes that changes in teaching practices 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 that is relevant, contextual, and future-oriented. A primary emphasis of educational advancement is improving instructors' expertise, particularly in the implementation of innovative and effective teaching methodologies. Training in the development of instructional modules is a theoretically substantiated approach for enhancing capacity.

This approach originates from the concept that educators facilitate significant learning experiences alongside the transmission of knowledge. Educators get training that familiarises them with pedagogical frameworks emphasising inquiry-based learning, student-centered approaches, and lesson design that integrates real-world situations. The development of instructional modules actualises theoretical instructional frameworks. STEM-based module design aligns with constructivist learning philosophy, which asserts that students gain knowledge through active involvement. Educators that undergo module development training are more proficient in internalising essential educational principles such as the alignment of learning objectives, instructional methodologies, and assessment. Moreover, it fosters self-sufficiency and introspective practice, both of which are essential for professional teaching competence. From a theoretical perspective, the creation of a teaching module enhances educators' understanding of curricular content, instructional design, and learner requirements, while simultaneously functioning as a cognitive and pedagogical exercise. By depicting educators as curriculum makers tasked with integrating and navigating diverse educational ideas into practice, it fosters the professionalisation of teaching. Consequently, enhancing teacher competency via module development training serves as both a theoretical and practical method to bolster the teacher's role as a learning architect.

CONCLUSIONS

The integration of the STEM approach into education, especially in the development of teaching materials, has become a necessity in facing technological advancements in the field of education. The STEM approach, which encompasses four disciplines, can be used as a teaching method to enhance students' critical thinking and problem-solving skills. However, one of the challenges frequently encountered today is the limitation of teachers in developing technology-based teaching materials. One of them is the development of Teaching Modules that can be implemented with a STEM approach in learning activities. The module must be well-structured and contain the necessary criteria for a teaching module with a learning approach. Therefore, to create a module that integrates the STEM approach, training is needed to enhance teachers' competencies in developing technology. The training conducted must support teachers in understanding the theoretical framework, designing integrative learning activities, and reflecting on the learning activities.

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