International Journal of STEM Education for Sustainability, Vol.6, No.1, 2026, pp. 73-82
e-ISSN 2798-5091. DOI. 10.52889/ijses.v6i1.760

Profiling STEM Literacy Among Kindergarten and Elementary School Teachers in Banten Province, Indonesia: A Descriptive Case Study

Submitted 17 November 2025, Revised 31 January 2026, Accepted 31 January 2026

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Abstract

For kindergarten and elementary school teachers to be ready to face the challenges of the 21st century, they must have STEM literacy. This study describes the definition of STEM literacy for kindergarten and elementary school teachers. This research employed a descriptive qualitative approach. By using a random sampling technique, the subjects of this research were kindergarten and elementary school teachers in Serang City, Banten, Indonesia. In this research, a STEM literacy questionnaire was employed, which consisted of three aspects: knowledge, attitudes, and skills. To gather data, a Google Form was distributed to kindergarten and elementary school teachers in Serang City. Then, the data was gathered and analyzed. The results indicate that most teachers have a good conceptual understanding of STEM as an integrative approach, but this understanding remains at a descriptive level and has not been fully implemented in learning practices. Systematic training is needed to strengthen the pedagogical implementation of STEM in a contextual and developmentally appropriate manner.

Keywords: STEM Literacy, Elementary Education, 21st-Century Skills

INTRODUCTION

Students need to have 21st-century skills, including digital literacy, creativity, collaboration, communication, and critical thinking, because of the development of the Industrial Revolution 4.0 and Society 5.0 (Trilling & Fadel, 2021; OECD, 2024). Thus, STEM (Science, Technology, Engineering, and Mathematics) education, as a response to develop the basis of these skills, is one of the most relevant and strategic ways to train people to overcome global challenges. STEM plays a crucial role because it integrates four interrelated disciplines to solve real-world problems through an interdisciplinary and project-based approach (Bybee, 2013; English, 2016). According to Schweingruber et al. (2014), STEM learning encourages students to understand science and technology concepts contextually, as well as develop engineering and mathematical skills in solving complex problems. UNESCO (2021) also revealed that in a social context, STEM helps strengthen environmental awareness, social responsibility, and the ability to contribute to sustainable development.

STEM is an ideal approach due to its benefits and integration of four disciplines. Integrating STEM from elementary to higher education is a crucial foundation for creating an innovative and competitive society (World Economic Forum, 2020). At the elementary and early childhood levels, the importance of STEM becomes even more apparent, as this is the period during which children develop their early cognitive and affective foundations. According to Liu et al. (2024), instilling STEM from an early age enhances children's curiosity,

observational skills, and problem-solving skills. These STEM experiences can foster curiosity, confidence in science, and long-term interest in careers in STEM fields (Larkin & Lowrie, 2022; McClure et al., 2017). Therefore, teachers play a central role as educators who facilitate meaningful learning experiences through exploration, play, and creative projects appropriate to children's developmental stages (Torres-Crospe et al., 2014; Margot & Kettler, 2019).

Teachers at this level are not simply transmitters of material, but exploratory facilitators who shape children's scientific thinking through concrete and enjoyable experiences (UNESCO, 2023). The ability to conduct STEM-based learning is related to teachers' STEM literacy. In the 21st century, STEM literacy is an essential skill for teachers. Bybee (2013) states that STEM literacy is not only the ability to understand concepts in mathematics, science, technology, and engineering, but also the application of these concepts in learning to improve the students' creative, critical, communication, and collaborative skills. As such, teachers need to have high STEM literacy skills. Lack of science and technology skills in high school and college education could be a result of low STEM literacy skills from a young age.

In Indonesia, STEM education for prospective teachers needs further development (Nugraha et al., 2023), both conceptually and pedagogically. Teachers' low understanding of STEM can result in science and mathematics learning remaining isolated, lacking integration of technology and engineering elements (Margot & Kettler, 2019). Furthermore, previous research tends to focus on secondary school teachers and pre-service teachers, while relatively few studies have examined kindergarten and elementary school teachers. Meanwhile, early childhood educators play a crucial role in developing the foundations of scientific thinking and children's curiosity.

Therefore, mapping the STEM literacy profiles of kindergarten and elementary school teachers is an urgent need to design interventions that are appropriate to the context of child development and the characteristics of teachers in the field. Furthermore, this study uses a profile mapping approach that includes aspects of knowledge, attitudes, self-efficacy, practices, and implementation barriers, providing a more comprehensive picture than conventional descriptive studies. This study also provides an overview of recommended activities or training that can develop STEM skills in elementary school teachers. The results of the study are also expected to provide input for policymakers in developing policies to improve STEM-based teacher competencies, so that learning in kindergarten and elementary school becomes more contextual and creative, as a form of adaptation to global change from an early age.

METHOD

This study used a quantitative descriptive approach supported by qualitative analysis aimed at obtaining a factual and systematic picture of the condition of teachers' STEM literacy (Creswell & Creswell, 2018). This approach is used to describe the STEM literacy profile of Kindergarten (TK) and Elementary School (SD) teachers in Banten Province based on their STEM knowledge, attitudes, and skills.

The participants of this study were randomly chosen kindergarten and elementary school teachers in Serang City, Banten, Indonesia. This study utilized a STEM literacy questionnaire, which includes three aspects: knowledge, attitudes, and skills. A qualitative research involves descriptive or open-ended questions, aiming to gain in-depth and comprehensive answers regarding STEM.

Data were collected through an online questionnaire by Google Form distributed to kindergarten and elementary school teachers in Serang City. Data collection was carried out by ensuring voluntary participation and confidentiality of respondents' identities in accordance with educational research ethics (Cohen et al., 2018). Next, the collected data was analyzed qualitatively, which was carried out on open-ended answers by reading all the data in depth.

RESULTS AND DISCUSSION

The STEM literacy of kindergarten and elementary school teachers was examined across three aspects: knowledge, attitudes, and STEM skills. Regarding knowledge, most kindergarten and elementary school teachers in this study understood the basic concept of STEM as an integrative approach that combines Science, Technology, Engineering, and Mathematics in a meaningful learning context. Teachers described STEM as learning that focuses on integrating four disciplines for the purpose of problem-solving, developing creativity, and applying concepts in everyday life.

The above findings show that the conceptual understanding of the characteristics of STEM learning by educators is good. But many teachers have a theoretical understanding of the concepts and have not yet been able to implement these concepts into effective teaching practices. This situation shows that there is a gap between the conceptual understanding of STEM learning and teaching practices. Teachers generally understand that STEM is an integration of science, technology, engineering, and mathematics, but they have not been able to design learning activities that interconnect STEM in a problem-solving or project-based way. This finding is in line with the findings of English (2016), who said that teachers find it difficult to implement engineering design practices and interdisciplinary problem-solving in the classroom. Similar evidence is reported by Margot and Kettler (2019), who found that limited

professional development, insufficient instructional resources, time constraints, and rigid curriculum structures are major factors that hinder effective STEM implementation. The impact of this condition is that STEM learning is frequently reduced to fragmented or surface-level integration, which limits students' opportunities to engage in higher-order thinking, collaborative problem solving, and authentic inquiry. Consequently, the potential of STEM education to foster 21st-century skills such as critical thinking, creativity, and technological literacy may not be optimally achieved. Without adequate pedagogical support and sustained professional learning, teachers' strong conceptual awareness of STEM risks remaining at the level of discourse rather than transforming into impactful instructional practice that benefits student learning outcomes.

Furthermore, teachers' understanding of STEM also influences the timing of STEM introduction. They agree that STEM needs to be introduced early. They emphasize that the incorporation of STEM in children from a young age can help develop curiosity and scientific thinking, as well as creativity, communication, collaboration, and critical thinking. To prepare children to meet the challenges of the world, it is necessary to develop these four skills from a young age (McClure et al., 2021). This is supported by Salahova (2021), who emphasizes that education incorporating STEM can help improve scientific intelligence in children. To improve scientific thinking skills in children, it is necessary that STEM education be designed properly, with scientific activities being adjusted according to the psychological development of children, and diagnostic and corrective procedures being followed.

Teachers also responded that through STEM, teachers can introduce science and technology in a contextual and fun way. Teachers argue that introducing STEM from an early age helps build motivation and interest in the field of science and technology in the future. This is in line with Eshach & Fried (2005), introducing STEM from an early age is believed to play an important role in building students' motivation and long-term interest in science and technology fields, as early STEM experiences help shape positive attitudes toward inquiry, experimentation, and innovation. Children become more open to innovation and are not afraid to try new things. Moreover, students learn that science, technology, engineering, and mathematics are not separate disciplines, but interconnected domains that can be applied to solve real-life problems in their environment, such as understanding how objects work, utilizing natural materials, or designing and creating simple tools (Bybee, 2013; Kelley & Knowles, 2016). This is supported by the teachers' belief that the implementation of STEM learning will result in noticeable changes in the students, such as an increase in their interest in learning and their tendency to question and analyze learning activities. This leads to the students'

improvement in critical thinking, creative thinking, and problem-solving skills in real-life situations (Becker & Park, 2011). From a cognitive point of view, STEM learning helps students gain a deeper understanding of concepts because they are directly involved in hands-on activities rather than just conceptual learning at a theoretical level (English & King, 2015). Moreover, affective aspects can also be seen, where the students become more self-reliant, have a stronger preference for collaborative learning, and exhibit higher curiosity levels during learning activities. The psychomotor domain is also improved because the students are more proficient in problem-solving and creating simple products or prototypes using design-based learning processes (Capraro & Slough, 2013; Kelley & Knowles, 2016).

Moving on, in the area of STEM attitudes, teachers showed a strong understanding that STEM is inextricably tied to economic, social, and environmental factors and is perceived as an essential part of people's lives. Teachers were able to articulate that STEM fuels innovation, enhances quality of life, generates employment, and offers solutions to different social and environmental problems. Statements like "STEM enhances economic competitiveness," "helps find sustainable solutions," or "is directly related to the real world" show that teachers have a clear understanding of the importance of STEM, not only as a learning strategy but also as a force that affects sustainable living.

The STEM literacy profile of the teachers shows that they have a high level of conceptual understanding, are able to grasp the overall significance of STEM to economic, social, and environmental development, and are able to offer simple examples of its application in the classroom. The answers given are still descriptive, not yet practical and applicable. This indicates that kindergarten and elementary school teachers do not yet have a good STEM literacy foundation and require strengthening in pedagogical and technical aspects to integrate STEM more systematically into kindergarten and elementary school learning. Research by Kade et al. (2024) on the implementation of the Project-Based Learning-based STEM model in secondary schools stated that although teachers showed high enthusiasm, the integration of technology and engineering aspects was still simple and required further guidance to become more complex. This is evident in the teachers' skills. Muthmainnah et al. (2025) found that many biology teachers (elementary level) in STEM-SDG training still need to deepen their knowledge of sustainable learning design and pedagogical literacy to link STEM to real social and environmental issues.

Next, regarding the STEM skills aspect. Based on the teachers' answers, it is evident that the STEM literacy of kindergarten and elementary school teachers is generally at a basic operational stage. This is indicated by their ability to provide various examples of science

activities that integrate Technology, Engineering, and Mathematics in simple and concrete forms. Science activities such as balloons inflating with vinegar and baking soda, rainbow tissue (capillarity), volcanic eruptions, elephant toothpaste, bottle tornadoes, and color experiments. These activities reflect teachers' understanding of teaching basic science concepts concretely through exploration and experimentation close to children's experiences. Simple engineering activities such as making bridges from popsicle sticks, balloon cars, rubber boats, and even The Lego structures show that teachers are conscious of the role of design, building, and problem-solving as integral parts of STEM education. The activity is in line with the engineering design process, which is identified as an important framework for improving problem-solving and creative thinking skills in early childhood and elementary education (Kelley & Knowles, 2016). In the mathematics domain, teachers provide developmentally appropriate examples, such as measuring objects in the classroom, counting items, and calculating volume, angles, distance, time, and speed, indicating their ability to integrate numerical reasoning into real-life contexts. This contextual integration of mathematics supports students' conceptual understanding and numeracy development (Fitzallen, 2015; McClure et al., 2017). Meanwhile, the use of technology is still largely limited to simple tools such as glue, scissors, and balloons; however, some teachers have begun to introduce digital technologies, including educational applications, laptops, and basic coding activities. The emergence of responses related to simple robotics and dirty water filtration projects suggests that several teachers possess more advanced STEM literacy, as they can design problem-based projects and real-world solutions that reflect the characteristics of contemporary STEM learning, namely interdisciplinarity, authenticity, and societal relevance (Bybee, 2018; Thibaut et al., 2018).

The data also shows that 40% of teachers have a good understanding of STEM because they can provide answers by directly integrating STEM aspects. Meanwhile, 60% of teachers still provide descriptive examples and do not illustrate the integration of STEM aspects. In line with Li et al. (2020), elementary school teachers tend to understand STEM as a collection of subjects, rather than as an integrative approach based on design and investigation processes. Furthermore, teachers' answers also indicate that they do not fully understand how to implement STEM in early childhood and elementary school learning, through activities that touch on aspects of exploration, observation, design, experimentation, and problem-solving. This indicates a literacy gap that can become a barrier. Some teachers are very strong and able to cite complex STEM projects, while others are still at a very basic level or cannot even provide examples. Margot and Kettler (2019) also stated that one of the main barriers for teachers in implementing STEM is the lack of authentic experience in designing integrative, problem-

solving-based activities. This indicates that teachers generally have a good initial willingness and understanding of STEM, but still need pedagogical reinforcement and targeted training to integrate STEM more systematically using a more explicit cross-disciplinary approach and integration.

This finding is further reinforced by teachers' responses, which indicate strong interest and high expectations for STEM education training that prioritizes practical and applicable integration in classroom learning. Study findings showed that STEM professional development workshops can provide insights into the support needed for teachers to adopt innovative, effective, project-based STEM approaches to teaching science in their schools (Siew et al., 2015). Recent studies emphasize that STEM-focused professional development programs are most effective when they provide opportunities for teachers to actively engage in hands-on, design-based, and project-oriented learning experiences, rather than relying solely on conceptual explanations (El-Deghaidy & Mansour, 2015). This is also supported by the responses of the teachers, who said that they were very interested and hoped for training on STEM education, which would focus more on practical STEM integration in learning. The training is expected to be more innovative and responsive to classroom realities, with a strong emphasis on engineering-based activities that enable teachers to understand how STEM learning can be adapted to the cognitive and developmental levels of kindergarten and elementary school students. Exposure to authentic engineering tasks during professional development has been shown to significantly enhance teachers' understanding of the engineering design process, including problem identification, iterative design, testing, and evaluation, which in turn influences their instructional practices (Ring et al., 2017). STEM involves engineering practices, which indirectly affects teachers' knowledge and teaching behaviours regarding engineering design, problem-solving procedures concerning engineering design, and experiences of scientists and engineers (Hasim et al., 2022). Moreover, STEM professional development that combines engineering and real-world problem-solving has a positive effect on teachers' pedagogical beliefs, which improves their educational beliefs (Hsu et al., 2017; Shernoff et al., 2017). These findings suggest that sustained, practice-oriented STEM training is essential not only for strengthening teachers' STEM literacy but also for promoting pedagogical transformation toward inquiry-based, student-centered learning environments that support the development of critical thinking, creativity, and problem-solving skills among young learners.

CONCLUSION

This is also supported by teachers' responses, which stated that they were very interested and hoped for training on STEM education, which would focus more on practical STEM integration in learning. Study findings show that STEM professional development workshops can provide insights into the support needed for teachers to adopt innovative, effective, project-based STEM approaches to teaching science in their schools. The training is expected to be more innovative and fresh, with a predominance of practical engineering activities that will certainly provide teachers with an overview of how to develop learning that is appropriate to the developmental level of kindergarten and elementary school students. STEM PD included engineering activities that indirectly had an extremely high impact on teachers' knowledge and teaching practices related to engineering design, the problem-solving process as it relates to the engineering design process, and the experiences of scientists and engineers

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