A STEM-Oriented Digital Mentoring Approach to Enhance Teachers' Digital Literacy in Primary Education

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Article Info

ABSTRACT

This study aims to analyse the effectiveness of STEM (Science, Technology, Engineering, and Mathematics) mentoring based on digital technology in enhancing the digital literacy of teachers, in response to the demands of 21st-century learning. Employing a mixed-methods action research design, the study involved four stages: planning, action, observation, and reflection. The participants consisted of 15 teachers from a Public Elementary School in Bogor, selected through purposive sampling. The mentoring programme included training in digital device usage, the development of STEM-based learning media, and the implementation of technology-driven projects. The findings demonstrate a significant improvement in the digital literacy of primary school teachers. Prior to the programme, the average digital literacy score was 58 (low category), which increased to 82 after the programme, confirming its effectiveness. The study highlights the potential of an integrated STEM and digital technology approach to improve teacher competencies. It also underlines the importance of continuous support through learning communities and access to digital resources to ensure the sustainability of professional development. Enhancing teachers' digital literacy is key to fostering innovative and relevant pedagogical strategies that align with the digital era. This research recommends broader application of similar mentoring models to improve the quality of basic education in Indonesia.

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Introduction

The rapid advancement of digital technology has significantly influenced various aspects of life, particularly in education. In the digital era, digital literacy has become a

fundamental skill for educators, enabling them to effectively utilize technology to enhance learning outcomes (Annisa & Widyasari, 2023; Lutfiana, 2024). A strong correlation has been established between teachers' digital literacy and their teaching effectiveness, which in turn affects student achievement (Fu, 2023; Zemlyanskaya & Dyrdina, 2023). Consequently, improving teachers' digital literacy is an urgent priority in educational reform. Digital literacy extends beyond the ability to operate technological devices; it includes the capacity to integrate technology meaningfully into the learning process. The STEM (Science, Technology, Engineering, and Mathematics) approach has been widely recognized as effective in fostering scientific attitudes, improving learning outcomes, and enhancing problem-solving skills among students (Nurmayanti & Kristayulita, 2024; Nurfirani & Kristayulita, 2024; Yuliardi & Andini, 2024).

Research indicates that a STEM-based learning approach enhances student engagement and activity during the learning process, thereby contributing to the development of enhanced mathematical problem-solving skills (Sudarsono & Mawaddah, 2024). In the context of Bogor city and district, educators continue to encounter difficulties in incorporating digital technology into the learning process. The obstacles encountered in achieving digital literacy are attributed to the absence of a unified framework and barriers such as limited access to technology and cultural variations, underscoring the necessity for a collaborative approach involving educators, government entities, and technology providers (Phippen, 2024; Neumeyer et al., 2020; Raihan et al., 2024).

Preliminary observations and consultations with multiple educators have revealed that a prevalent challenge is the limited comprehension and proficiency in the implementation of digital technology in STEM education among educators. This phenomenon can be attributed to a number of factors, namely: 1). Limited Access to Training: A significant proportion of the teaching faculty have not received adequate training in digital literacy and digital technology-based STEM applications. This has resulted in their limited understanding and proficiency in the effective utilisation of digital technology in the learning process. In countries such as Indonesia, where digital literacy levels are moderate and uneven, rural teachers encounter difficulties in accessing adequate training opportunities, thereby hindering their professional development and their capacity to serve as role models for students in the context of digital media (Anggraini & Kusumaningrum, 2023).

Teachers encounter obstacles in accessing digital-based STEM training due to an inadequate focus on cultivating the requisite skills and attitudes, impeding their digital literacy development and integration in teaching practices (Mannila et al., 2018). 2) The absence of adequate technology facilities is a salient issue. It is evident that a number of schools within the region have yet to be equipped with the necessary technology facilities to facilitate STEM-based learning in conjunction with digital technology. The limited access to laptops, poor connectivity, and minimal digital literacy training pose challenges for teachers in online STEM training (Hanson & Beem, 2022). The absence of technological resources for educators to implement digital-based learning engenders a substantial challenge to enhancing their digital literacy and integrating technology effectively in education (Purmayanti, 2022; Stoika, 2023; Thumbarayan et al., 2023). This hinders teachers' ability to implement innovative and interactive learning methods. 3). Lack of Mentoring: Teachers require intensive mentoring to facilitate the integration of digital technology into STEM curriculum and learning processes. This mentoring is important to ensure that teachers can overcome the barriers they face and can implement digital technology with confidence. There is a need for increased teacher training to address gaps in digital literacy across STEM subjects (Vieira et al., 2023).

This study aims to improve the digital literacy of teachers at Public Elementary School in Bogor through a structured mentoring program based on digital technology and STEM principles. By doing so, it seeks to empower educators to integrate technology into their teaching practices and provide high-quality learning experiences that meet the demands of 21st-century education. The study also addresses the need for sustainable professional development models tailored to schools with limited digital access. The importance of ongoing digital technology training programmes in enhancing educators' digital literacy skills, particularly in rural areas where governmental and policy maker attention is imperative, is underscored (Lutfiana, 2024; Soekamto et al., 2022; Kerkhoff & Makubuya, 2022).

This research presents novelty through the integration of a STEM-based mentoring approach in the realm of digital literacy for elementary school teachers, which has rarely been explored in depth within the context of primary education. This novelty lies in the active role of technology in continuously supporting teachers through structured, contextual, and applicative digital mentoring strategies in STEM-based learning. Thus, teachers' digital literacy can improve and influence their teaching strategies in the classroom. The significance of this research is evident in its contribution to addressing the challenge of low digital competence among teachers in the era of educational digital transformation, while simultaneously strengthening teachers' capacity to design and implement adaptive, innovative, and relevant STEM learning that meets the needs of 21st-century learners.

Method

This study employed a mixed methods approach, utilising an action research design that encompassed four distinct stages: planning, action, observation, and reflection which is described in Figure 1 based on (Creswell & Creswell, 2017). The research subjects were 15 teachers from a Public Elementary School in Bogor, selected using a purposive sampling technique. These teachers lacked in-depth understanding of STEM, but showed willingness to participate in a three-month mentoring programme.

The research was conducted in a school with access to basic digital technology. Data collection involved administering questionnaires to assess teachers' digital literacy before and after the programme, conducting in-depth interviews to explore their experiences and challenges, observing the implementation of STEM-based learning, and documenting the learning products created by teachers.

The mentoring programme included training, technical guidance, and direct assistance in designing and implementing STEM-based learning using digital technology. The collected data were analysed quantitatively using descriptive statistics and paired sample t-tests to evaluate improvements in teachers' digital literacy. Qualitative data were analysed thematically to identify key insights from interviews and observations.

Data validity was ensured through triangulation by comparing the results of questionnaires, interviews, and observations. This research is expected to show significant improvement in teachers' digital literacy, establish an effective STEM mentoring model based on digital technology, and highlight facilitating and hindering factors in STEM implementation. This approach is intended to enhance the quality of learning in primary schools and serve as a model for similar initiatives in other institutions.

Figure 1. Research Method Flowchart

Results and Discussion

This study aimed to enhance the digital literacy of elementary school teachers at Public Elementary School in Bogor through a digital technology-based STEM mentoring program. The findings indicate a significant improvement in teachers' digital competencies following the implementation of the program. Quantitative analysis showed that the mean digital literacy score increased from 58 (categorized as low) to 82 (high) after the mentoring program. The results of the paired sample t-test yielded a p-value of < 0.05, indicating a statistically significant improvement in digital literacy. All participants showed progress, with those initially scoring lower demonstrating the most substantial gains. In addition to the quantitative findings, qualitative data from interviews and observations revealed that teachers experienced increased confidence in integrating digital technology into their lesson plans. They successfully used tools such as simulation applications and basic coding platforms like Micro:bit. Teachers also developed digital learning products that were relevant, creative, and aligned with students' needs. However, several challenges were noted. Limited access to technological devices and internet connectivity were reported as major obstacles. Furthermore, some teachers initially struggled to grasp STEM concepts. Nevertheless, these challenges were gradually overcome through ongoing technical guidance, peer collaboration, and problem-solving discussions during mentoring sessions.

Significant enhancements in digital literacy serve to demonstrate the efficacy of digital technology-based STEM mentoring approaches (de Lima & Schnitman, 2024). The provision of hands-on training has been demonstrated to facilitate a deeper comprehension amongst educators of the application of technology within the learning context. This finding lends further support to the notion that experiential training is a pivotal factor in enhancing teachers' competencies, a concept that has been previously emphasised in research. In this study, teachers underwent training that was both theoretical and hands-on, encompassing the utilisation of the Canva app for designing learning materials and the Scratch program for fundamental coding education (Mannila et al., 2018; Al Haq et al., 2024).

The integration of STEM approaches with digital technology is also relevant to the principles of contextualised learning (Triplett, 2023). Teachers are taught to relate technology to learning materials that are relevant to students' daily lives. For instance, in a specific learning project, educators employed digital simulations to elucidate the concept of energy transformation, engaging students in coding-based experiments (Rajasekaran et al., 2024). This pedagogical approach has been shown to enhance teachers' digital literacy skills and enrich students' learning experiences, rendering them more interactive and meaningful (Phippen, 2024; Marín & Castaneda, 2022).

Whilst the findings demonstrate the efficacy of the programme, the challenges encountered by teaching staff underscore the necessity for sustained support. The scarcity of technology devices at SDN Bojong is identified as a significant impediment to the effective implementation of STEM-based learning. To address this, recommendations have been made to the government and relevant stakeholders, including the provision of adequate technology devices and the enhancement of technology infrastructure within educational institutions, particularly in resource-constrained settings (Annisa & Widyasari, 2023).

In line with these results, the mentoring program also fostered a shift in teachers' pedagogical perspectives. Teachers began to perceive digital tools not merely as add-ons but as integral components of student-centered STEM learning. They reported increased motivation to innovate and to experiment with interdisciplinary approaches, combining science, technology, engineering, and mathematics with digital applications to create more engaging and meaningful learning experiences. This pedagogical shift indicates not only an improvement in technical proficiency but also a transformation in teaching mindset—one that aligns with 21st-century education goals and the demands of digital-native learners.

Moreover, the success of the program underscores the importance of sustained mentorship and contextualized training in building digital capacity among educators in primary education. The program's structure—combining training, peer reflection, and problem-solving—proved effective in bridging the gap between theoretical knowledge and classroom practice. It also highlights that digital literacy development cannot be separated from ongoing professional support and collaborative learning environments. These insights suggest that similar digital-STEM mentoring frameworks could be adapted and scaled across other schools to systematically enhance teacher readiness for technology integration in diverse educational settings.

Furthermore, the findings underscore the significance of ongoing professional development for educators, as evidenced by the reluctance of some teachers to engage with STEM practices, as highlighted in the Mannila et al. (2018) study. The enhancement of mentoring programmes can be facilitated through the provision of online training or microlearning-based learning modules, thereby enabling teachers to learn flexibly according to their own time. This strategy has the potential to assist teachers who feel constrained by time and workload in maintaining and enhancing their competencies.

This research has both practical and theoretical implications. In terms of its practical application, the mentoring model utilised can function as a template for the development of analogous programmes in other educational institutions. The efficacy of an approach grounded in hands-on experience and contextual relevance in enhancing teachers' digital literacy has been demonstrated (Kadarisman et al., 2022). From a theoretical standpoint, this study underscores the significance of the constructivist approach in education, wherein knowledge is co-constructed through direct experience by teachers and students.

Future research should explore the impact of digital technology-based STEM approaches on student learning outcomes. Furthermore, the integration of emerging technologies, such as artificial intelligence (AI), within STEM learning environments has the potential to yield significant advancements in the field. By continuously evaluating and developing this approach, STEM-based learning has the potential to make a significant contribution to the transformation of education in the digital era.

The mentoring programme was found to be an effective tool in enhancing teachers' digital literacy at SDN Bojong, though it is acknowledged that certain technical and pedagogical challenges persist. With adequate support and the implementation of innovative training strategies, the integration of digital technology-based STEM approaches holds considerable potential for enhancing the quality of learning in primary schools.

Conclusion

This study demonstrates that digital technology-based STEM mentoring significantly enhances the digital literacy of primary school teachers. The intervention led to a notable improvement in participants' digital literacy, with the average score increasing from 58 (low category) to 82 (high category), thus confirming the effectiveness of the program. Beyond technical skills, the mentoring enabled teachers to meaningfully integrate digital tools into

STEM-oriented instructional practices. The program's success is attributed to its experiential and contextually relevant approach. Nevertheless, challenges such as limited technological resources and internet connectivity remain and must be addressed. Sustained support through infrastructure development and continuous professional training is essential to ensure the scalability and long-term impact of such initiatives across broader educational contexts.

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