SPEKTA
(Jurnal Pengabdian Kepada Masyarakat: Teknologi dan Aplikasi)
ISSN 2723-8016 (online) | 2723-8008 (print)
Vol 7, No. 1, pp. 82-93

Dissemination of AI Utilization to Elementary School Teachers towards the Realization of STEM Class

Murein Miksa Mardhia[1*], Dwi Normawati[1], Risanti Dhaniaputri[2], Fiorella Adistya Moniaga[1], Aisyah Dwi Puspita[1], Yoga Rusydi Arifin[1], Muhammad Musthofa Masyhur[1], Haura Nidaulhaq[2], Dhea Aprilia Ayu[2]
[1]Informatics, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2]Biology Education, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
*Corresponding Author: murein.miksa@tif.uad.ac.id

ARTICLE INFO

Article history
Received February 4, 2026
Revised May 8, 2026
Accepted June 3, 2026

Keywords
Artificial intelligence;
Digital transformation;
Elementary school;
Teachers;
STEM class.

ABSTRACT

Background: The rapid advancement of science and technology requires elementary school students to develop core competencies in Science, Technology, Engineering and Mathematics (STEM), along with early digital literacy. However, STEM implementation in primary education remains limited due to inadequate infrastructure, disparities in teacher competence, and minimal exposure to emerging technologies such as Artificial Intelligence (AI).
Contribution: This program introduces an integrated training framework that simultaneously combines STEM learning, computational thinking, and practical AI applications for elementary school teachers.
Method: An evaluative approach with a quantitative descriptive design was employed. The program was conducted in three stages: preparation, training, and evaluation. The preparation stage involved needs analysis through classroom observations and interviews. The training stage consisted of two intensive sessions covering computational thinking, basic coding using Scratch, generative AI, AI ethics, and prompt engineering.
Results: The results demonstrate a measurable improvement in teachers' competencies, with the average percentage score increasing from 66% to 84%. The most significant improvements were observed in algorithmic understanding, computational thinking, ethical awareness of AI usage, and the application of digital tools such as Scratch and AI-assisted design platforms.
Conclusion: The program effectively enhanced teacher readiness to implement structured STEM learning and demonstrated the potential of integrating AI into teacher professional development at the elementary level.

1. Introduction

Human resource development plays a crucial role in improving the quality of basic education, particularly in preparing students to meet the demands of the 21st century. Educational stakeholders, including schools, parents, and communities, must collaborate to create a learning environment that supports the development of science and mathematics literacy, critical and creative thinking, basic technological skills, and adaptive and collaborative competencies. These competencies are essentially not only for academic achievement but also for enabling students to compete and innovate in an increasingly global and technology-driven environment [1], [2].

Despite these expectations, the implementation of such competencies in elementary education remains challenging. Internally, schools often face limitations in infrastructure, such as inadequate laboratories, insufficient experimental materials, and a lack of interactive learning media. Additionally, teacher competencies in STEM pedagogy vary significantly, with many educators lacking formal training in designing project-based learning activities or integrating digital technologies effectively. Curriculum constraints and administrative workloads further restrict the implementation of sustained and iterative STEM activities in the classroom [3]–[5].

To address these challenges, teacher capacity building through targeted training programs has been widely recognized as a key strategy. Previous studies have emphasized the importance of STEM-based learning and the integration of digital technologies to enhance teaching effectiveness. In parallel, the emergence of AI offers new opportunities to support teaching and learning processes, including interactive content creation, adaptive learning, and automation of instructional tasks [5]–[7].

However, existing studies and training programs tend to address STEM pedagogy and digital technology separately, and there remains a lack of structured initiatives that integrate AI, computational thinking, and STEM learning simultaneously, particularly for elementary school teachers. This gap highlights the need for a comprehensive and integrated training approach that aligns technological tools with pedagogical practices suitable for primary education [8]–[10].

From an external perspective, parental and community support for STEM education is not yet fully optimized. Many parents still emphasize traditional, test-oriented learning outcomes, limiting the adoption of exploratory and student-centered approaches. Socioeconomic factors also influence students' access to digital resources, such as internet connectivity and devices, while limited school budgets constrain the implementation of innovative educational programs.

Muhammadiyah Sokonandi Elementary School represents a relevant case, as it demonstrated strong potential for educational innovation but still faces challenges in implementing structured and sustainable STEM programs. Current initiatives remain sporadic and largely dependent on individual teacher efforts, while the absence of a structured STEM-based curriculum and systematic evaluation mechanisms limits the ability to measure learning outcomes effectively. Therefore, this program aims to implement and evaluate a structured community service activities designed to enhance teachers' competencies through the integration of STEM pedagogy, computational thinking, and AI-based tools. The novelty of this program lies in its holistic approach, which combines technical skill development, pedagogical strategies, and ethical awareness of AI within a single training framework tailored for elementary education. This approach is expected to support sustainable STEM implementation and contribute to improving the overall quality of basic education.

2. Method

This program employed an evaluative approach with a quantitative descriptive design to assess the effectiveness of a community service program in improving teachers' competencies in STEM and AI integration. The implementation of the program consisted of three main stages: preparation, training, and evaluation, as illustrated in Figure 1.

Figure 1. Stages of Activity Implementation

2.1. Planning/Preparation Stage

The preparation stage began with an initial coordination meeting to define the objectives, implementation schedule, and success indicators of the program. A needs analysis was then conducted through classroom observations and semi-structured interviews with teachers to identify challenges related to STEM implementation, digital literacy, and the availability of learning resources [11]. Observations focused on infrastructure conditions, including teaching aids, classroom environment, and the availability of materials [12]. Interviews explored teacher profiles, including class size, students' basic science competencies, and existing teaching practices. Based on these findings, training modules, teacher modules, teacher guides, assessment instruments, and STEM teaching aids were developed and adapted to the local context [12]–[14].

2.2. Workshop/Training Stage

The workshop stage was conducted in two sessions involving 20 elementary school teachers. The first session focused on introducing computational thinking concepts, basic coding using Scratch, and the application of generative AI for developing interactive learning media. The second session addressed the practical use of ChatGPT [15]; AI ethics [16], [17]; prompt engineering techniques [18], [19]; and the integration of STEM-based teaching aids [20], [21] in classroom settings. Both sessions were designed to incorporate hands-on activities to ensure that participants not only developed theoretical understanding but also acquired practical skills applicable to real classroom situations.

 https://doi.org/10.12928/spekta.v7i1.15783

Figure 2. Documentation of Workshop Activities during the Community Service Program. Training and Practices

2.3. Evaluation Stage

To measure the effectiveness of the training, a pre-test and post-test design was applied during the activities [21]. The evaluation instrument consisted of 20 items (P1-P20) measured using a five-point Likert scale (1=strongly disagree to 5=strongly agree). The instrument assessed two categories: knowledge and skill aspect [22]. The knowledge aspect was defined in a broader sense to include not only conceptual understanding but also awareness, perceived applicability, perceived usefulness, and learning orientation (P1–P6, P8–P12, P15, P18, and P19). Meanwhile, the Skill aspect includes items related to practical abilities, confidence, and readiness to apply coding and AI tools in educational contexts (P7 and P13–P14, P16–P17, and P20). The collected data were treated as quantitative data and analyzed using descriptive statistics, particularly by comparing the mean scores between pre-test and post-test results. The difference in mean scores was used as an indicator of improvement in teachers' knowledge and skills following the training.

3. Results and Discussion

3.1. Results

The program was implemented through three stages: preparation, workshop and evaluation. During the preparation stage, observations and interviews conducted at Muhammadiyah Sokonandi Elementary School identified a strong need to develop structured STEM learning. Teachers reported limited experience in integrating AI and computational thinking into classroom practices, confirming the need for targeted capacity-building interventions. The workshop stage consisted of two intensive sessions conducted in a fully equipped computer laboratory. Each session combined theoretical explanations with hands-on activities to ensure the development of both conceptual understanding and practical skills.

3.2. Practical Outputs and Community Impacts

In addition to improve teacher competencies, the program also generated several tangible outputs that support sustainable implementation of STEM- and AI-based learning at Muhammadiyah Sokonandi Elementary School. These outputs included activity documentation (Figure 2), STEM teaching aids that were formally handed over and tested in classrooms settings, training modules for teachers (Figure 3), and a website developed as a centralized platform for documenting and disseminating community service activities and learning resources (Figure 4). Collectively, these outputs demonstrate the program's contribution not only to teacher professional development but also to the provision of sustainable educational resources that can continue to be utilized beyond the duration of the program.

(a)

(b)

Figure 3. (a) STEM Teaching aids: AI and Robotic Tools; and (b) Training Modules produced for Teachers' Learning Resources

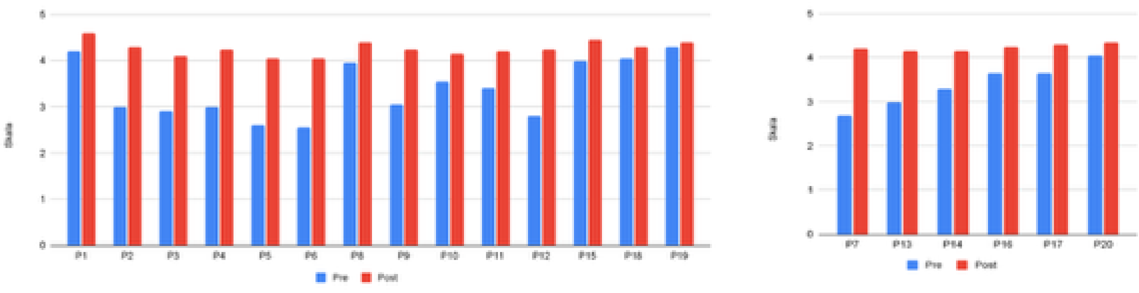
The effectiveness of the workshop was evaluated using pre-test and post-test instruments (Figure 5). The results indicate a consistent improvement in both knowledge and skills across participants. In the first training session, which focused on coding and generative AI, participants demonstrated notable improvements in conceptual understanding. The highest

 https://doi.org/10.12928/spekta.v7i1.15783

increase was observed in participants' understanding of the distinction between algorithms and coding, with a mean difference of 1.3 points. Additional improvements were found in computational thinking (P3, Δ = 1.2) and the ability to apply algorithmic concepts in real=life contexts (P4, Δ = 1.25).

Figure 4. Web-based Application developed for Community Service Information Portal

In terms of practical skills, the largest improvement was recorded in the ability to use Scratch for instructional purposes (Δ = 1.5). Other significant gains included prompt engineering skills (P13, Δ = 1.15) and the use of AI-assisted tools such as Canva (P14, Δ = 0.85). The second training session, which focused on AI ethics and STEM teaching aids, also showed positive outcomes. Improvements were observed in participants' understanding of AI regulations, effective prompt usage, and the application of STEM teaching aids (P4–P6, Δ ≈ 1.05). Furthermore, participants' self-assessed skill confidence increased, with post-test scores exceeding an average of 3 across all indicators, suggesting a satisfactory level of competency development following the training.



(a) (b)

Figure 5. Evaluation Results during Activities for (a) Knowledge Aspects, and (b) Skill Aspects

The findings in this program indicate that the integration of computational thinking, coding, and AI-based tools within a structured training program can effectively improve teachers' competencies in STEM education. The observed increase in both knowledge and practical skills suggests that hands-on, technology-integrated training plays a crucial role in bridging the gap between theoretical understanding and classroom implementation. This result supports recent findings that emphasize the role of AI-enabled technologies in enhancing educators' instructional capacity and transforming teaching practices [23]. In addition, the integration of computational thinking with AI-based approaches is consistent with studies showing that AO-supported learning environments can foster problem-solving abilities and strengthen computational thinking skills in STEM education [24]–[26].

The significant improvement in algorithmic understanding and computational thinking reflects the effectiveness of introducing foundational digital concepts through interactive platforms such as Scratch. This finding aligns with previous studies emphasizing that computational thinking enhances problem-solving abilities and supports STEM learning in primary education. Moreover, the improvement in algorithmic understanding and AI tool utilization indicates that teachers were able to adapt to emerging technologies when provided with guided practice and contextualized learning materials. This supports the argument that AI can serve as a valuable tool in enhancing instructional design, particularly in generating learning content and facilitating creative teaching approaches [27].

The inclusion of AI ethics in the training also contributed to participants' awareness of responsible technology use. This is particularly important in educational contexts, where the misuse of AI tools may lead to ethical concerns such as academic dishonesty or overdependence on automated systems. The findings suggest that combining technical training with ethical considerations is essential in preparing teachers for sustainable digital transformation. From a practical perspective, the use of STEM teaching aids and hands-on activities contributed to increased teacher confidence and readiness to implement interactive learning strategies. This indicates that experiential learning approaches are effective in supporting teacher professional development.

In addition to the observed quantitative improvements, participants also reported several perceived benefits of the training, which were summarized into key thematic categories. Out of 20 participants, 15 participants (75%) highlighted hands-on practice as the most beneficial aspect, particularly in developing educational content such as games, interactive learning activities, and instructional materials [28], [29]. This finding indicates that experiential learning plays a central role in enhancing both engagement and skill acquisition.

The use of AI including prompt engineering and tools such as Perplexity AI [30], was also perceived as highly beneficial by 13 participants (65%). Participants reported that these tools significantly supported the efficient development of learning materials, including question generation and module preparation. This suggests that generative AI plays a critical role in enhancing productivity within instructional design by enabling rapid content generation and facilitating adaptive learning material development. This finding aligns with previous research indicating that generative AI contributes to educational advancement by transforming instructional design processes and enabling more efficient and innovative teaching practices [31], [32]. Furthermore, 11 participants (55%) identified coding and the use of Scratch as valuable components of the training, particularly for creating simple interactive learning applications. This reflects the potential of coding education to foster creativity and support

 https://doi.org/10.12928/spekta.v7i1.15783

problem-based learning approaches in elementary classrooms. In addition, 8 participants (40%) stated that all aspects of the training were beneficial, especially in improving their understanding of the role of AI in teaching and learning processes. Overall, these findings demonstrate that the training not only improved competencies but also generated positive perceptions toward the integration of AI and STEM in education.

Despite these positive outcomes, qualitative feedback from participants revealed several areas that require further support. Out of 20 participants, 70% expressed the need for continued assistance in developing AI-based teaching materials, particularly in creating visual-based assessment items, instructional modules, and AI-generated learning media. Furthermore, 12 participants (60%) reported difficulties in effectively utilizing AI tools such as Canva AI, Perplexity and prompt engineering techniques, indicating that initial exposure requires reinforcement through guided practice. In the domain of computational thinking, 10 participants (50%) highlighted the need for deeper mentoring in coding design and the practical use of Scratch. Additionally, 8 participants (40%) emphasized challenges in developing categorized assessment models and implementing practice-based activities. These findings suggest that while the training was effective in improving initial competencies, sustained mentoring and iterative practice are necessary to ensure long-term implementation in classroom settings.

Figure 6. Pilot Classroom and Hands-on Demonstration of STEM Teaching Aids

Following the training activities, a pilot classroom session (Figure 6) was conducted to allow teachers to directly implement and demonstrate the STEM teaching aids and AI-assisted learning approaches with elementary school students. During this session, teachers applied the instructional materials, computational thinking activities, and interactive teaching tools introduced in the workshop within real classroom settings. This follow-up implementation provided participants with practical experience in adapting the training outcomes to authentic learning environments and demonstrated the potential applicability of the developed resources for supporting STEM-based learning in elementary education.

While Figure 7 illustrates the follow-up meeting conducted between the community service team and school representatives prior to the implementation of the STEM and AI-based learning program. The meeting focused on identifying school needs, determining training schedules, discussing classroom implementation strategies, and aligning learning objectives with the school context. During the coordination meeting, school representatives explained that the planned STEM class initiative would adopt the implementation model previously used in the school's specialized Tahfidz class and English class programs, both of which had been successfully established and managed. In this context, the teacher capacity-building activities conducted through this community service program were considered an initial strategic foundation for supporting the future establishment of a STEM-based class and curriculum for 4th Grade students in the upcoming academic year. This indicates that the program not only contributed to short-term competency improvement but also supported the school's long-term educational development strategy toward STEM-oriented learning implementation.

Figure 7. Coordination Meeting for STEM Class Implementation

However, this community service program still has several limitations. The number participants were limited, and the training duration was relatively short, which may affect the generalizability of the findings. Additionally, the evaluation focused primarily on short-term outcomes, without measuring long-term impacts on classroom practices or student learning outcomes. Despite these limitations, the findings highlight the potential for scaling similar programs in other schools. Future programs should consider continuous mentoring, integration into formal curricula, and ongoing evaluation to assess sustained impact.

4. Conclusion

The implementation of STEM-based science and technology classroom development activities at Muhammadiyah Sokonandi Elementary School has had a significant positive impact on improving teacher competency, both in terms of knowledge and skills. Through two training phases focused on coding, the use of Artificial Intelligence (AI), and the use of STEM teaching aids, teachers demonstrated improved understanding of basic educational technology concepts and their practical application in the classroom. Pre-test and post-test evaluations indicated an increase in teachers' understanding of algorithms, computational thinking, engineering prompts, and their ability to use digital platforms such as Scratch and

 https://doi.org/10.12928/spekta.v7i1.15783

Canva AI as teaching aids. Furthermore, training on the ethics of AI usage equipped teachers with professional awareness to implement technology responsibly and in accordance with educational values.

In terms of implementation, this program also successfully strengthened the school's readiness to build a structured STEM learning ecosystem through the provision of teaching modules, interactive teaching aids, and project-based learning guides. The long-term impact of this activity is expected to encourage teachers to become agents of innovation in science and technology learning, as well as foster students' interest and abilities in STEM fields from an early age. Thus, this training activity can be concluded as a strategic step in supporting the transformation of basic education toward 21st-century learning that is technology-based, collaborative, and adaptive to developments in artificial intelligence. The success of this activity also provides an important foundation for the development of follow-up programs focused on ongoing teacher mentoring and strengthening collaboration between schools, universities, and the education community.

Acknowledgement

The authors would like to express their sincere gratitude to the Directorate of Research and Community Service (DPPM), Ministry of Higher Education, Science and Technology (Kemdiktisaintek), for the financial support under the Community-Based Empowerment (Pemberdayaan berbasis Masyarakat) grant scheme (Contract No. 037/PkM/LPPM.UAD/XI/2025). The authors declare no conflict of interest. Author Contribution: All authors contributed equally to the conception, design and writing of this study to this paper. All authors have read and approved the final paper.

References

[1] W. R. Penuel, R. Riedy, M. S. Barber, D. J. Peurach, W. A. LeBouef, and T. Clark, “Principles of Collaborative Education Research With Stakeholders: Toward Requirements for a New Research and Development Infrastructure,” *Rev. Educ. Res.*, vol. 90, no. 5, pp. 627–674, Oct. 2020, https://doi.org/10.3102/0034654320938126

[2] L. I. González-Pérez and M. S. Ramírez-Montoya, “Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review,” *Sustainability*, vol. 14, no. 3, p. 1493, Jan. 2022, https://doi.org/10.3390/su14031493

[3] E. Rizkasari, Yufiarti, D. Yatimah, and M. S. Sumantri, “The importance of developing elementary school teachers’ pedagogical competencies in 21st century education,” *AIP Conf. Proceedings*, 2024, https://doi.org/10.1063/5.0242521/20277916/040041_1_5.0242521

[4] V. Sukmayadi and A. Yahya, “Indonesian education landscape and the 21st century challenges,” *J. Soc. Stud. Educ. Research*, 2020, https://jsser.org/index.php/jsser/article/view/901

[5] C. Marouli, “Sustainability Education for the Future? Challenges and Implications for Education and Pedagogy in the 21st Century,” *Sustainability*, vol. 13, no. 5, p. 2901, Mar. 2021, https://doi.org/10.3390/su13052901

[6] A. Oancea, N. Fancourt, J. Robson, I. Thompson, A. Childs, and N. Nuseibeh, "Research capacity-building in teacher education," *Oxford Rev. Educ.*, vol. 47, no. 1, pp. 98–119, Jan. 2021, https://doi.org/10.1080/03054985.2020.1842184

[7] J. Kim, "Leading teachers' perspective on teacher-AI collaboration in education," *Educ. Inf. Technol.*, vol. 29, no. 7, pp. 8693–8724, May 2024, https://doi.org/10.1007/s10639-023-12109-5

[8] S. S. Lodhi and S. Lodhi, "Integration of AI in STEM education, addressing ethical challenges in K-12 settings," *arXiv Prepr. arXiv2510.19196*, 2025, https://arxiv.org/abs/2510.19196

[9] A. H. Nguyen, D. M. Nguyen, A. D. Do, L. T. H. Nguyen, and B. Q. Tran, "Integration of AI in STEM Education: A Systematic Review," *Proc.* , 2025, https://doi.org/10.1145/3731806.3743504

[10] M. Nawaz, "AI in STEM Education: Enhancing Problem-Solving and Critical Thinking Skills," *AI EDIFY Journal*. 2024.

[11] D. Filmer, E. Molina, and W. Wane, *Identifying effective teachers: lessons from four classroom observation tools*. assets.publishing.service.gov.uk, 2020.

[12] A. Siddique, Y. Waqar, and A. Raza, "Teachers' perspectives on availability of infrastructure and resources: a quantitative study based on gender and sector," *jsom*. academia.edu, 2023, https://doi.org/10.56976/jsom.v2i3.40

[13] K. Greitans and D. Namsone, "Identification of Science Teacher Profiles Based on Lesson Observation Data," *Sci. Educ. Int.*, vol. 35, no. 2, pp. 102–108, Jun. 2024, https://doi.org/10.33828/sei.v35.i2.4

[14] M. S. Ramírez-Montoya, M. I. Loaiza-Aguirre, A. Zúñiga-Ojeda, and M. Portuguez-Castro, "Characterization of the Teaching Profile within the Framework of Education 4.0," *Futur. Internet*, vol. 13, no. 4, p. 91, Apr. 2021, https://doi.org/10.3390/fi13040091

[15] H. Mondal, G. Marndi, J. K. Behera, and S. Mondal, "ChatGPT for Teachers: Practical Examples for Utilizing Artificial Intelligence for Educational Purposes," *Indian J. Vasc. Endovasc. Surg.*, vol. 10, no. 3, pp. 200–205, Jul. 2023, https://doi.org/10.4103/ijves.ijves_37_23

[16] M. Usher and M. Barak, "Unpacking the role of AI ethics online education for science and engineering students," *Int. J. STEM Educ.*, vol. 11, no. 1, p. 35, Aug. 2024, https://doi.org/10.1186/s40594-024-00493-4

[17] J. Borenstein and A. Howard, "Emerging challenges in AI and the need for AI ethics education," *AI Ethics*, vol. 1, no. 1, pp. 61–65, Feb. 2021, https://doi.org/10.1007/s43681-020-00002-7

[18] Y. Qian, "Prompt Engineering in Education: A Systematic Review of Approaches and Educational Applications," *J. Educ. Comput. Res.*, vol. 63, no. 7–8, pp. 1782–1818, Dec. 2025, https://doi.org/10.1177/07356331251365189

[19] D. Lee and E. Palmer, "Prompt engineering in higher education: a systematic review to help inform curricula," *Int. J. Educ. Technol. High. Educ.*, vol. 22, no. 1, p. 7, Feb. 2025, https://doi.org/10.1186/s41239-025-00503-7

[20] I. Gustiani, A. Widodo, and I. R. Suwarma, "Development and validation of science, technology, engineering and mathematics (STEM) based instructional material," *AIP*

Conf. Proc., 2017, https://doi.org/10.1063/1.4983969/13745121/060001_1_online

[21] A. Swandi, "Student Learning Outcomes and Teacher Perception in Science Learning Using Low-Cost Teaching Aids with the STEM Approach," in *2025 10th International STEM Education Conference (iSTEM-Ed)*, Jul. 2025, pp. 1–6, https://doi.org/10.1109/iSTEM-Ed65612.2025.11129282

[22] L. A. T. Nguyen and A. Habók, "Tools for assessing teacher digital literacy: a review," *J. Comput. Educ.*, vol. 11, no. 1, pp. 305–346, Mar. 2024, https://doi.org/10.1007/s40692-022-00257-5

[23] H. Avci, S. J. Lunn, and Z. Hazari, "Exploring STEM educators' perspectives on the integration of AI-enabled technologies in teaching and learning," *Comput. Educ. Open*, vol. 9, p. 100304, Dec. 2025, https://doi.org/10.1016/j.caeo.2025.100304

[24] M. A. Ayanwale and C. B. Omeh, "AI-supported problem-based learning for enhancing computational thinking skills in STEM education," *Comput. Hum. Behav. Artif. Humans*, vol. 7, p. 100263, Mar. 2026, https://doi.org/10.1016/j.chbah.2026.100263

[25] A. Al-Ansi, V. Ryabtsev, and T. Utkina, "The use of a vision system for monitoring chick embryos in incubator," *SPEKTA (Jurnal Pengabdian Kepada Masyarakat Teknologi dan Aplikasi)*. 2023, https://doi.org/10.12928/spekta.v4i2.8450

[26] N. Kholifah, J. Puspito, S. Sunarta, M. Nurtanto, and M. Nurtanto, "Development and Implementation of Smart Eco-STEAM Technology to Reduce Defects and Improve Efficiency in Ecoprint MSMEs," *SPEKTA (Jurnal Pengabdian Kepada Masyarakat Teknologi dan Aplikasi).* 2025, https://doi.org/10.12928/spekta.v6i2.14481

[27] A. Subarno, C. Dyah Sulistyaningrum Indrawati, P. Ninghardjanti, W. Winarno, and M. Choerul Umam, "Enhancing AI-Powered PowerPoint Skills: Training Impact on Vocational Teachers in Surakarta," *SPEKTA (Jurnal Pengabdi. Kpd. Masy. Teknol. dan Apl.*, vol. 6, no. 1, pp. 122–141, 2025, https://doi.org/10.12928/spekta.v6i1.13056

[28] J. I. C. and C. N. Nwadiokwu, "Enhancing Student Engagement through Practical Production and Utilization of Instructional Materials in an Educational Technology Class: A Multifaceted Approach," *NIU J. Educ. Res.*, vol. 10, no. 2, Sep. 2024, https://doi.org/10.58709/niujed.v10i2.2002

[29] H. Khotimah and N. Hidayat, "Interactive Digital Comic Teaching Materials to Increase Student Engagement and Learning Outcomes," *Int. J. Elem. Educ.*, vol. 6, no. 2, pp. 245–258, Jun. 2022, https://doi.org/10.23887/ijee.v6i2.46038

[30] S. Rahmawati and N. L. Inayati, "Utilization of Artificial Intelligence (AI) Perplexity as a Digital Literacy Tool for Islamic Religious Education Students," *Iseedu J. Islam. Educ. Thoughts Pract.*, vol. 8, no. 2, pp. 205–214, Nov. 2024, doi: https://doi.org/10.23917/iseedu.v8i2.9001

[31] J. Lv, "Generative AI, Educational Advancement and Instructional Design Innovation," *Advances in Social Science, Education and Humanities Research*, pp. 879–884, 2025, https://doi.org/10.2991/978-2-38476-509-6_97

[32] L. I. Ruiz-Rojas, P. Acosta-Vargas, J. De-Moreta-Llovet, and M. Gonzalez-Rodriguez, "Empowering Education with Generative Artificial Intelligence Tools: Approach with an Instructional Design Matrix," *Sustainability*, vol. 15, no. 15, p. 11524, Jul. 2023, doi: https://doi.org/10.3390/su151511524