EDUMATSAINS
JURNAL PENDIDIKAN MATEMATIKA DAN SAINS
E-ISSN:2527-7235
Volume 10 Issue. 4, April 2026, pp 276-290
http://ejournal.uki.ac.id/index.php/edumatsains

Strategies for Preparing Teachers for Coding and Artificial Intelligence Education

Noris Rahmatullah[1], St Fatimah Azzahra[2]
[1]Ministry of Primary and Secondary Education of the Republic of Indonesia
[2] Department of Chemistry Education, Faculty of Teacher Training and Education, Indonesian Christian University

e-mail: norisrahamtullah@gmail.com

Article Info
Article history:
Received: April 7th, 2026
Revised: April 29th, 2026
Accepted: April 30th, 2026
Available online: April 30th, 2026

https://doi.org/10.33541/edumatsains.v10i4.8078

Abstract
The implementation of Coding and Artificial Intelligence (AI) as a subject within the national curriculum requires a high level of teacher readiness, while most teachers come from non-ICT backgrounds and face limitations in infrastructure and learning resources. This study aims to describe the implementation of teacher preparation for instruction through collaboration between the Ministry of Primary and Secondary Education (Kemendikdasmen) and Training Provider Institutions, as well as to identify its outcomes and challenges. This research employed a descriptive quantitative approach involving 10,061 teachers from primary, junior, and senior high school. Data were collected through online and offline questionnaires, supported by interviews and document analysis. The results indicate that the teacher's preparation was conducted in a structured and phased manner through In-Service Training 1 (IN1), On-the-Job Training (OJT), and In-Service Training 2 (IN2), supported by an integrated quality assurance system. The average level of participants' understanding reached 82%, and most teachers reported being ready to teach. However, several challenges remain, including limited pedagogical competence among non-ICT teachers, inadequate infrastructure, and unstable internet access. Coding and Artificial Intelligence instruction was implemented using unplugged, plugged, and internet-based approaches, which encourage collaborative and project-based learning. This study concludes that the collaboration between Ministry of Primary and Secondary Education and Training Provider Institutions is effective in preparing teachers for CAI instruction. Continuous mentoring and the strengthening of the school ecosystem are key factors for the successful implementation of adaptive CAI learning that is relevant to the demands of 21st-century education.

Keywords: Teacher Preparation, Coding, Artificial Inteligence

1. Introduction

One of the fundamental objectives of the establishment of the Republic of Indonesia is to educate the people. Accordingly, the state bears the responsibility to develop a national education system that aims to enhance faith, piety, and noble character as integral components of national intellectual development. Indonesia law (UU No 20 Tahun 2003) defines national education as an integrated set of educational components that function cohesively to achieve national educational objectives. In this context, the state is obligated to create a conducive learning environment in which the educational process is intentionally designed to enable learners to actively develop their potential. Through such processes, learners are expected to acquire spiritual and religious strength, self-regulation, personal integrity, intellectual competence, moral character, and the skills necessary for their personal development as well as for the advancement of society, the nation, and the state.

Indonesia missions to achieve “Indonesia Emas 2045” is articulated in the national plan 2025-2045 (RPJPN - Rencana Pembangunan Jangka Panjang Nasional), which envisions the Republic of Indonesia as a unified, sovereign, advanced, and sustainable nation supported by high-quality human resources, a progressive culture, and the capacity to contribute to global civilization. The digital competencies of Indonesia’s human resources are a critical determinant of national progress and competitiveness, particularly in the era of Industry 4.0, which is characterized by digitalization, networked systems, big data, artificial intelligence technologies, and robotics (Mahiri, Najoua, Soueda, & Amini, 2023). Respond to the demands of Industry 4.0, the Indonesia must prepare students to compete globally through mastery of digital technologies. In addition to student preparedness, enhancing teachers’ competencies—particularly their ability to adapt and innovate in instructional practices—is essential for addressing global challenges (Faliki, Nurkhasanah, Soraya, & Chamdani, 2025). In response, the government has undertaken several adjustments to the national curriculum to better equip students with the competencies required to meet global challenges.

The Government, through the Ministry of Primary and Secondary Education (Kemendikdasmen), issued Regulation (Permendikdasmen 13 Tahun 2025) which formally incorporates Coding and Artificial Intelligence (AI) into the national curriculum structure as an elective subject. This subject is scheduled to be implemented gradually beginning in the 2025–2026 academic year. There are a lot of research has examined the implementation of coding and artificial intelligence (AI) in learning contexts; however, studies focusing on teacher preparedness for these subjects remain limited. Moreover, coding and AI have only recently been introduced as formal subjects at the national level in the 2025/2026 academic year. This gap highlights the significance and timeliness of the present study in addressing the critical issue of teacher readiness for effective implementation. Coding and AI are introduced from Grade 5 of primary school through Grade 12 of senior secondary education (general and vocational). The subject not only develops students’ technical programming skills but also fosters critical thinking, creativity, and problem-solving abilities, with learning content focused on computational thinking, digital literacy, programming algorithms, data analysis, and ethics (Awaluddin & Hadi, 2025). Instruction in

Coding and AI may be delivered through intracurricular, co-curricular, or extracurricular formats. As a newly introduced subject, its implementation presents several challenges, particularly in terms of infrastructure readiness and teacher preparation, which must be addressed to ensure effective adoption across educational institutions.

The fulfillment of qualified teacher needs by the Ministry is generally conducted through teacher certification programs and the establishment of professional learning communities, such as Teacher Activity Centers (Pusat Kegiatan Guru/PKG), Subject Teacher Associations (Musyawarah Guru Mata Pelajaran/MGMP), and Teacher Working Groups (Kelompok Kerja Guru/KKG) (Rafsanjani, et al., 2023). In addition to these approaches, the Ministry has introduced an innovative strategy to address the demand for teachers of Coding and Artificial Intelligence (CAI) by implementing a training mechanism in collaboration with Training Provider Institutions (Lembaga Penyelenggara Diklat/LPD). These institutions are responsible for training and mentoring both in-service teachers and prospective teachers who will teach CAI subjects. Through collaboration with LPDs, the training of prospective CAI teachers can be conducted at scale and simultaneously across districts and city. This study aims to examine the implementation of CAI teacher preparation through collaboration with LPDs and to assess how such collaboration supports teachers in effectively conducting the learning process.

2. Methods

This a quantitative approach study using a descriptive research design. Descriptive research aims to provide a systematic depiction of phenomena or conditions as they occur (Yusuf A. M., 2014). Accordingly, this study seeks to describe the strategies implemented by the Ministry in preparing teachers for Coding and Artificial Intelligence (CAI) instruction. The instrument's validity and reliability were established through a series of statistical tests. Content validity was confirmed through expert judgment, while construct validity was assessed using item-total correlation, with all items showing coefficients exceeding the critical value at a 0.05 significance level. Reliability was evaluated using Cronbach's Alpha, yielding a coefficient of 0.83 value, which surpassed the acceptable threshold of 0.70, indicating good internal consistency. These results demonstrate that the instrument is both valid and reliable for data collection.

Respondents were selected using purposive sampling. Purposive sampling is a sampling technique in which participants are chosen based on predefined criteria determined by the researchers from a target population (Kurniawan & Puspitaningtyas, 2016). The study respondents consisted of school teachers from the primary level (n = 6,842), lower secondary level (n = 1,718), upper secondary level (n = 810), and vocational secondary level (n = 691), resulting in a total sample of 10,061 teachers. The sampled teachers included primary classroom teachers, informatics-related subject teachers, science (STEM) subject teachers, as well as teachers of other subjects assigned by school principals to participate in the Coding and Artificial Intelligence (CAI) training. These teachers received CAI training from Training Provider Institutions corresponding to their respective regions. The study was conducted between June and September, in accordance with the locations where the training programs were implemented.

The research data used in this study were collected through a questionnaire. A research questionnaire is a primary data collection technique used to obtain information from a number of respondents who constitute the research sample (Wekke, 2019). Data collection via the questionnaire was conducted using both online and offline modes, complemented by interviews with selected respondents. The interviews were carried out to confirm and clarify several findings obtained from the online questionnaire, as well as to validate supporting documents. In quantitative research, the questionnaire serves as the primary research instrument, while interviews function as a supporting instrument to enhance the credibility of the data (Samsu, 2017).

3. Result and Discussion

a. Implementation

The preparation of teachers for Coding and Artificial Intelligence (CAI) instruction is conducted through collaboration among multiple stakeholders, including the Ministry of Primary and Secondary Education (Kemendikdasmen), local governments, and Training Provider Institutions (LPDs). Kemendikdasmen is responsible for formulating the norms, procedures, and criteria for CAI training programs, designating LPDs, providing technical guidance to LPDs, and ensuring quality assurance in the implementation of training. Province and Distric or City play a supporting role in facilitating the implementation of CAI instructional policies by working with schools to provide resources and support for teachers assigned to teach CAI subjects, as well as by facilitating the establishment of Teacher Working Groups (Kelompok Kerja Guru/KKG) and Subject Teacher Associations (Musyawarah Guru Mata Pelajaran/MGMP) for CAI.
In the training of prospective Coding and AI teachers, LPDs are responsible for developing training materials, coordinating with relevant institutions, delivering training programs to prospective teachers, and conducting internal quality assurance of CAI training. The implementation of CAI training is carried out in a continuous and structured manner through In-Service Training 1 (IN-1), On-the-Job Training (OJT), and In-Service Training 2 (IN-2). CAI training programs delivered by LPDs are implemented according to the designated working areas or regions of each LPD. The CAI training process is organized into three main stages, namely:

1) Preparation

The preparation stages begin with the development of Norms, Standards, Procedures, and Criteria (NSPC) for the training program, which include technical training guidelines, training work plans, and training instruments such as learning outcomes, objectives and indicators, program structure, syllabus, and evaluation plans. This phase also involves the establishment of a Memorandum of Understanding (MoU) between the Directorate General of Teachers and Education Personnel and the designated Training Provider Institutions (LPDs). Training for prospective Coding and Artificial Intelligence (CAI) teachers may only be conducted by Centers for Teachers and Education Personnel Development—including the National Centers (BBGTK), Regional Centers (BGTK), Offices for Teachers and Education Personnel (KGTK)—and LPDs that meet the

required criteria and are formally appointed by the Director General of Primary and Secondary Education.
Facilitators or instructors for prospective CAI teachers are required to hold at least a bachelor's degree (S1/DIV), have a minimum of two years of teaching experience, demonstrate proficiency in the use of computers or laptops, and possess a background in informatics-related teaching. Teacher training is further supported by a Management Information System (MIS) and a Learning Management System (LMS) developed by the Ministry. Prior to delivering training to prospective CAI teachers, facilitators participate in technical guidance programs designed to equip them with the training content, adult learning (andragogical) strategies, and competencies in using the LMS.
Facilitators are responsible for moderating discussions within the LMS and in face-to-face training sessions, reinforcing key concepts and materials, providing feedback, and delivering on-site mentoring for a minimum of 24 hours (3 × 8 hours) during the On-the-Job Training (OJT) phase. The technical guidance for facilitators employs a deep learning approach, emphasizing experiential learning through understanding, application, and reflection, delivered through both online and offline modalities. Following the technical guidance, facilitators undergo a competency assessment, upon which they receive an evaluation rating. Facilitators who successfully pass the competency assessment are awarded a certificate, signifying their eligibility to conduct training for CAI teachers.

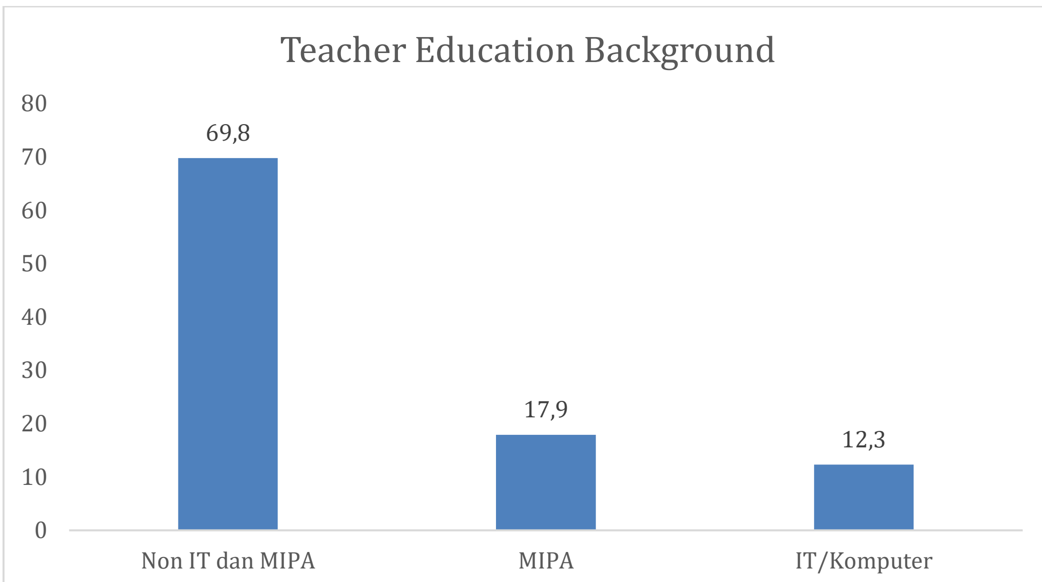
2) Training
In-Service Training 1 (IN-1) was conducted during the July–August 2025 period and organized within the respective working areas of each Training Provider Institution (LPD). Teacher training comprised 40 sessions, with each session equivalent to 45 minutes. Following the completion of IN-1, Coding and Artificial Intelligence (CAI) teachers implemented classroom instruction through On-the-Job Training (OJT) at their respective educational institutions during the August–October 2025 period. During OJT, facilitators monitored and mentored teachers through both online and face-to-face modalities to observe the implementation of training outcomes in actual instructional settings.

Upon completion of OJT, CAI teachers were reconvened by the LPDs to participate in In-Service Training 2 (IN-2), which was conducted during the October–November 2025 period. During IN-2, facilitators facilitated reflective sessions focusing on the instructional practices implemented by CAI teachers during the OJT stage.

Throughout all training stages—IN-1, OJT, and IN-2—LPDs continuously implemented quality assurance mechanisms through systematic reflection and improvement processes. During the IN-1 stage, relevant units within Kemendikdasmen conducted site visits and monitoring activities to assess the implementation of training and to provide feedback for the subsequent OJT phase. Monitoring was conducted involving training participants, facilitators, local education authorities, and educational institutions. Monitoring samples were selected using purposive sampling, involving 1,700 training participants who were prospective CAI teachers. Purposive sampling is a technique for determining samples based on specific considerations (Sugiyono, 2013). In addition, data were collected through an online survey administered to all training participants, totaling 10,061 respondents. Surveys are systematic data collection methods conducted by a group of researchers to obtain information from a defined population (Yusuf M. , 2017).

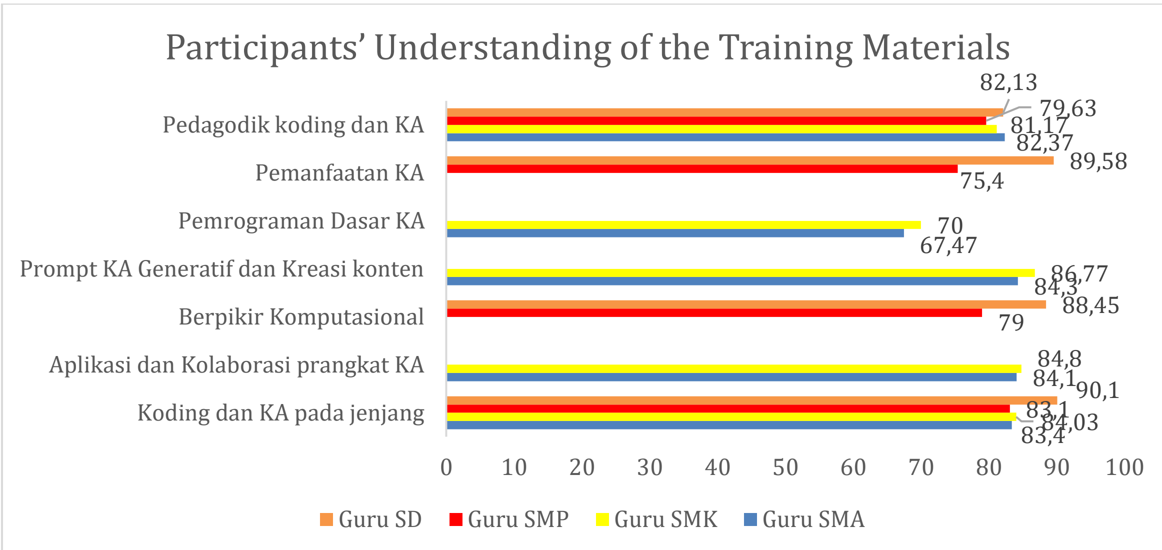
Monitoring and evaluation conducted by the Ministry, as reported by the Center for Education Policy Studies (PSKP) during the IN-1 phase, indicated that teachers participating in the Coding and AI training predominantly came from mathematics, natural sciences, and other subject areas, with the majority having non-IT and non-STEM educational backgrounds.

Figure 1. Distribution of Teachers' Highest Educational Attainment in the Training Program



Approximately 69.8% of the teachers participating in the Coding and Artificial Intelligence (AI) training program came from non-IT and non-STEM (science, technology, engineering, and mathematics) educational backgrounds, representing 1,689 teachers in total. Most participants demonstrated limited foundational knowledge in information technology, requiring facilitators to adopt specialized instructional strategies in both content delivery and mentoring. Facilitators were therefore expected to ensure that participants comprehensively understood the training materials. To accommodate participants' diverse backgrounds and learning needs, facilitators employed various pedagogical approaches, including problem-based learning, project-based learning, collaborative learning, and inquiry-based learning. In addition, learning media such as digital learning platforms, learning management systems (LMS), and artificial intelligence applications were utilized to support participants' comprehension of the training content. Upon completion of all training modules, facilitators conducted assessments to evaluate participants' levels of understanding.

Figure 2. Training Participants' Assessment Results



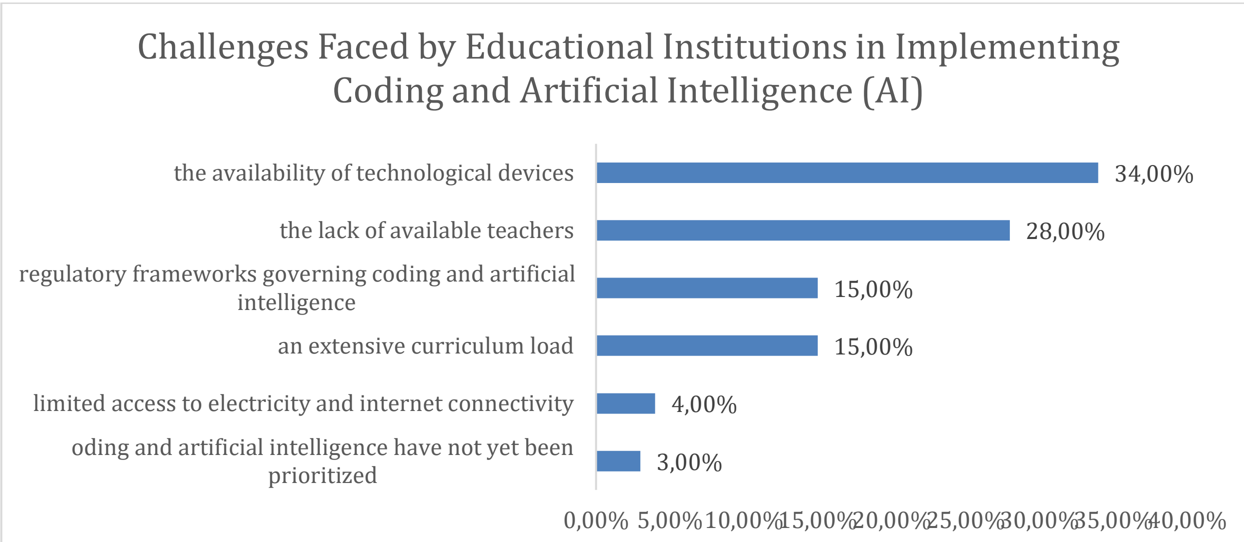
The overall average level of participants' understanding of the training materials reached 82%. The materials perceived as the easiest to understand were those related to the pedagogy of Coding and Artificial Intelligence (AI) and foundational knowledge of Coding and AI across educational levels. In training programs for senior high school (SMA) and vocational high school (SMK) teachers, programming-related content was identified as the most challenging. Difficulties in understanding programming materials were largely attributed to the high proportion of participants with non-IT educational backgrounds, which required a longer learning period.

In contrast, training for elementary (SD) and junior high school (SMP) teachers did not include programming content but instead focused on foundational programming concepts through computational thinking. This material was also considered challenging for SD and SMP teachers. Given the varying levels of difficulty across training materials, 64% of participants reported that the training duration was sufficient, while 34% indicated that the duration should be extended, and 2.1% suggested that it should be reduced. Requests for additional training time were primarily associated with materials perceived as difficult to understand. Overall, participants demonstrated a satisfactory level of comprehension of most training components.

Following the completion of IN-1 training, 86.6% of teachers reported that they felt ready to teach Coding and AI. However, facilitators provided a more cautious assessment, indicating that only 55% of teachers were fully ready, 13.8% were not yet ready, and 31.2% were partially ready to teach Coding and AI.

In terms of institutional readiness, 75.7% of the 1,698 surveyed schools stated that they were prepared to implement Coding and AI as a subject, while 24.3% reported that they were not yet ready. Schools that had not implemented Coding and AI identified significant barriers, particularly related to the availability of infrastructure and qualified teaching personnel. These constraints contributed to institutional unpreparedness, despite the fact that teachers had already completed training provided by the LPD.

Figure 3. Challenges Faced by Educational Institutions in Implementing Coding and Artificial Intelligence (AI)



Several key points were identified regarding the IN-1 training. The participants' average level of content comprehension reached 82%, while their readiness level was 86.6%. These results indicate that further improvement is required to ensure that teachers are fully prepared to effectively teach Coding and Artificial Intelligence (AI) subjects.

Following the completion of the IN1 training, teachers returned to their respective educational institutions to implement Coding and AI instruction. During this phase, facilitators monitored the implementation process and provided feedback as well as support to assist teachers in conducting Coding and AI learning activities. In addition, the Directorate General of Primary and Secondary Education provided ongoing mentoring to both teachers and LPDs throughout the on-the-job training (OJT) period.

3) Quality Insurance

Quality assurance for the Coding and Artificial Intelligence (AI) training is conducted by the Directorate General of Teachers and Education Personnel (Direktorat Jenderal Guru dan Tenaga Kependidikan-Ditjen GTK), with the objective of ensuring that all training processes comply with established process standards and guidelines. The quality assurance of the Coding and AI training is implemented in a comprehensive and integrated manner, encompassing both quality control and quality improvement frameworks.

In addition to the quality assurance conducted by the Ditjen GTK, internal quality assurance is also carried out by the LPD, beginning from the preparation stage, through implementation, and continuing to the follow-up of the implementation phase. Furthermore, the training activities organized by the LPD are subject to monitoring and evaluation mechanisms that are integrated into the “Ruang GTK” platform.

b. Barriers, Challenges, and Solutions

During the implementation of Coding and Artificial Intelligence (AI) instruction, some teachers were still in the process of adapting to Coding and AI concepts, particularly non-ICT teachers and those approaching retirement age. In contrast to ICT teachers, non-ICT teachers and teachers nearing retirement generally required a longer period to adapt to the teaching and learning of Coding and AI in classroom settings.

Teachers were able to deliver the initial learning materials effectively, as the early stages of instruction focused on introductory concepts of Coding and AI. However, when the learning process progressed to core or more advanced topics, such as programming logic, teachers began to encounter difficulties in facilitating students’ understanding.

At this stage, the role of the school principal as an instructional supervisor becomes critical. School principals play an essential role in coordinating policies, providing administrative support, and facilitating collaboration with education authorities, foundations (in private schools), parents, and external partners. Principals are also responsible for ensuring the readiness of human resources, setting realistic learning targets, and sustaining the implementation of the Coding and AI program. In addition to the role of school principals, facilitators also play a vital role in supporting the implementation of Coding and AI instruction in the classroom. Facilitators act as professional partners for teachers, providing consultation and collaborative discussion when teachers experience challenges during the instructional process.

Another challenge faced by teachers in implementing Coding and Artificial Intelligence (AI) instruction relates to the adequacy of infrastructure and learning facilities, including the availability of laboratories, laptops or computers, and reliable internet connectivity. Such infrastructure is particularly essential when delivering instructional content related to introductory AI concepts and programming activities.

Teachers serve as the frontline actors in the implementation of Coding and Artificial Intelligence (KKA) education. They encounter challenges in understanding programming logic, mapping learning outcomes, and maintaining students’ engagement during hands-on practice. To address these challenges, teachers employ collaborative learning strategies, hands-on activities, and the use of AI-based tools such as ChatGPT and Gemini to design engaging learning media.

Various forms of reinforcement can be implemented to support teachers in optimizing the delivery of Coding and AI instruction. Intensive teacher mentoring has been shown to strengthen teachers’ capacity to implement Coding and AI learning effectively in the classroom. The mentoring focuses on enhancing pedagogical competencies, applying instructional modules, and improving reflective practices as well as collaboration among teachers. Documentation of best practices is shared through learning management systems (LMS) or WhatsApp groups as a means of fostering collaboration between participants and facilitators. Peer teachers and facilitators provide feedback on instructional flow, learning media, and teacher–student interactions, while facilitators also conduct pedagogical and technical reviews to ensure alignment between classroom implementation and the prescribed learning modules. During the on-the-job training (OJT) phase, peer teaching activities are conducted to provide teachers with opportunities to teach and evaluate instructional practices directly.

The implementation of Coding and Artificial Intelligence (AI) instruction in schools demonstrates a collective commitment and growing awareness among teachers to develop technology-based teaching practices, although the level of implementation and consistency varies across schools. Most schools have established learning communities (Komunitas Belajar-Kombel)) or internal discussion forums that serve as platforms for sharing teaching experiences. These forums typically involve Coding and AI teachers, ICT teachers, school principals, and teachers from various subject areas. The frequency of meetings varies, ranging from weekly to monthly sessions. Informal discussions conducted through teachers' common rooms or WhatsApp groups are also utilized as alternative spaces for professional dialogue and collaborative learning. The topics discussed within these professional learning forums are diverse, including lesson planning, development of instructional media, integration of Coding and AI content into other subjects, and the use of various AI-based applications and tools. Several schools also use these forums for disseminating training outcomes and reflecting on instructional practices, including the sharing of teaching modules and best practices.

Another frequently encountered challenge is the limited availability of technological devices, such as laptops or personal computer (PC). The mismatch between the number of devices and the number of students necessitates rotational use during instructional activities. To address this issue, some schools allow students to bring personal devices and optimize the scheduled use of computer laboratories. In addition, unstable internet connectivity is mitigated through the flexible use of plugged and unplugged instructional approaches. Limitations in access to paid applications also constrain instructional implementation; however, most schools have addressed this challenge by utilizing free applications and openly accessible online resources.

c. Result and Outcome

The outcomes and impacts of the Coding and Artificial Intelligence (AI) training, as well as the facilitation provided by the LPD, can be observed through the instructional process. This process relates to how teachers conduct classroom teaching and how students respond to and engage with Coding and AI learning materials.

Learning Process

The implementation of Coding and Artificial Intelligence (AI) learning across various schools has been carried out in a gradual, adaptive, and contextual manner through the application of three main approaches: unplugged, plugged, and internet-based learning. The combination of these approaches is tailored to the availability of infrastructure, student characteristics, and the readiness of teachers and schools.

The unplugged approach is widely utilized, particularly during the initial stages of learning and in schools with limited access to digital devices. Through activities such as student worksheets, educational games, role-playing, simulations, case analyses, and contextual projects, students are trained to understand core computational thinking concepts, including decomposition, pattern recognition, algorithms, and abstraction, without the use of digital tools. This approach has proven effective in fostering logical reasoning, digital ethics, and collaborative skills.

The plugged approach serves as a crucial mode for hands-on practice using digital devices such as laptops, Chromebooks, smart TVs, or smartphones. In this approach, students directly engage in coding activities, data processing, and the application of artificial intelligence. It strengthens technical competencies and enhances technology-based problem-solving skills. Meanwhile, internet-based learning functions as a medium for exploration and knowledge expansion by utilizing online resources such as YouTube, Google, and various artificial intelligence (AI) digital platforms. This mode supports generative and collaborative learning, enabling students to explore real-world and interdisciplinary applications of AI.

Pedagogically, Coding and AI instruction is implemented through a combination of instructional models, including Problem-Based Learning (PBL), Understanding by Design, and Project-Based Learning (PjBL) (Nababan, Marpaung, & Koresy, 2023). Teachers play an active role as facilitators and reflective guides, supporting students in bridging theoretical understanding and practical application through discussions, demonstrations, presentations of learning outcomes, and feedback. The learning content encompasses: (1) an introduction to coding and computational thinking; (2) fundamental concepts and applications of artificial intelligence; (3) digital ethics and literacy; and (4) the integration of AI into everyday life and across subject areas.

Overall, the implementation of Coding and AI learning aligns with 21st-century education, emphasizing creativity, collaboration, communication, and critical thinking skills (Kusuma, et al., 2025).

Students Respons

Overall, the implementation of Coding and Artificial Intelligence (AI) learning received highly positive responses from both students and teachers. Students demonstrated strong enthusiasm and positive attitudes toward learning activities that were perceived as engaging, relevant, and distinct from other subjects. Active student engagement was evident through participation in discussions, eagerness in hands-on practices, and heightened interest when learning was connected to technologies commonly used in daily life, such as YouTube, Google Translate, Canva, and ChatGPT. The application-oriented and project-based nature of the learning activities emerged as a key factor in fostering student motivation and curiosity.

In terms of conceptual understanding, the majority of students were able to grasp the fundamental concepts of Coding and AI, particularly in more concrete topics such as AI introduction, basic computational thinking, and the use of interactive applications such as Scratch or Canva. Students' understanding improved significantly when teachers employed contextual, visual, and practice-based instructional approaches. However, challenges began to emerge when students encountered more abstract and technical content, including algorithms, programming logic, and the Python programming language. Unfamiliar terminology, code structures, and complex logical flows often posed difficulties, particularly for students with limited digital literacy skills.

Teachers perceived that Coding and AI instruction had a tangible positive impact on student development. Students became more logical, creative, and confident in their use of technology. Hands-on activities supported the development of critical and collaborative thinking skills, while the integration of AI into learning activities enhanced the perceived relevance of instruction to real-world contexts. Teachers also emphasized the importance of gradual learning progression and differentiated instruction to ensure that all students could engage effectively.

Although Coding and AI learning can be implemented using unplugged approaches, notable differences in student understanding were observed when compared to plugged and internet-based approaches. Variations in students' prior knowledge and interests further contributed to disparities in learning outcomes. In addition, limited instructional time constrained some students' opportunities to engage with the material in greater depth.

In general, both teachers and students regarded Coding and AI learning as highly beneficial, as it not only introduces technological concepts but also cultivates essential 21st-century skills, including problem-solving, collaboration, and creativity. With adequate infrastructural support and the application of contextualized instructional approaches, Coding and AI holds strong potential as an effective educational innovation for preparing learners to adapt to rapid technological and artificial intelligence advancements.

Coding and artificial intelligence (AI) hold strong potential as transformative educational innovations for preparing learners to adapt to rapid technological change. Recent studies emphasize that Computational Thinking has become a core 21st-century competency, enabling learners to solve complex problems, design systems, and engage in higher-order thinking required in technology-driven environments (Tariq, Babines, Alvarez-Icaza, & Naseer, 2024). The integration of coding into education has been empirically shown to significantly enhance students' computational thinking skills, creativity, and problem-solving abilities across educational levels (K.A, 2024). Furthermore, emerging evidence indicates that AI-supported learning environments contribute to the development of AI literacy and adaptive competencies, which are essential for navigating complex digital ecosystems (Hu, He, & Guan, 2025). These findings are reinforced by recent reviews highlighting that the convergence of coding, AI, and design-based learning fosters deeper cognitive engagement and innovation skills relevant to future workforce demands (Chih-Hung Wu, 2025). Therefore, the integration of coding and AI in education is increasingly recognized as a strategic approach to equipping learners with the critical competencies needed to thrive in an era of rapid technological and artificial intelligence advancement.

4. Conclusion

Teacher preparation for Coding and Artificial Intelligence (AI) instruction represents the outcome of a strategic collaboration among the Ministry of Primary and Secondary Education, local governments, and Regional Training Institutions (Lembaga Pelatihan Daerah/LPD). The Coding and AI training program was implemented in a structured and continuous manner through three stages: In-Service Training 1 (IN1), On-the-Job Training (OJT), and In-Service Training 2 (IN2). This staged approach ensured that teachers not only acquired theoretical knowledge but also developed the capacity to apply training outcomes within authentic classroom contexts.

In practice, Coding and AI instruction was delivered using three primary approaches—unplugged, plugged, and internet-based learning—adapted to school conditions and resource availability. Teachers employed instructional models such as Problem-Based Learning, Project-Based Learning, and Understanding by Design, thereby fostering contextualized, collaborative, and creative learning environments. The instructional content encompassed computational thinking, basic programming concepts, digital literacy, and the application of AI in everyday life.

Despite generally successful implementation, several challenges persisted, including limited access to technological devices, inadequate internet connectivity, and varying levels of pedagogical readiness among non-ICT teachers. Support from school principals and facilitators emerged as a critical factor in addressing these challenges through academic supervision, collaborative practices, and reflective mentoring.

To mitigate these constraints, targeted strengthening strategies were implemented, including intensive mentoring, peer teaching, documentation of best practices, and the establishment of professional learning communities (*Komunitas Belajar*). These forums facilitated experience sharing, reflective practice, and the reinforcement of cross-disciplinary teacher networks.

The impact of the training and subsequent implementation was largely positive. Teachers became more adaptive in their use of technology, students demonstrated increased enthusiasm and critical engagement, and learning processes became more interactive and relevant to 21st-century demands. Coding and AI instruction was shown to cultivate creativity, collaboration, communication, and critical thinking skills, while simultaneously fostering an innovative culture within schools.

Overall, the program underscores that technology-based educational transformation requires not only teacher training but also a supportive collaborative ecosystem, sustained mentoring, and consistent infrastructural and policy support. Through institutional synergy and continuous capacity building, Coding and AI hold significant potential as a key driver of future-oriented learning that is intelligent, adaptive, and globally competitive.

5. Acknowledgments

The authors would like to express their sincere gratitude to the Ministry of Primary and Secondary Education of the Republic of Indonesia for its support and facilitation in the implementation of this research. The guidance, policies, and educational initiatives provided by the Ministry have significantly contributed to the development and improvement of educational practices.

We would also like to extend our deepest appreciation to the Department of Chemistry Education for its academic support, valuable insights, and constructive feedback throughout this study. The collaboration and encouragement from the faculty members have greatly enriched the quality of this work.

Finally, we are truly thankful to all parties who have directly and indirectly supported the completion of this research.

6. References

Awaluddin, & Hadi, M. S. (2025, Maret). Integrasi Pembelajaran Koding dan Kecerdasan Buatan di Sekolah Dasar: Tantangan dan Peluang. Pendas : Jurnal Ilmiah Pendidikan Dasar, 10(1), 1081-1086.

Chih-Hung Wu, Y.-C. C.-T.-M. (2025). Integrating computational thinking, game design, and design thinking: a scoping review on trends, applications, and implications for education. HUMANITIES AND SOCIAL SCIENCES COMMUNICATIONS, 12(163), 1-12.

Faliki, A. N., Nurkhasanah, A. T., Soraya, E., & Chamdani, M. (2025). Meningkatkan Kualitas Guru untuk Menjawab Tantangan Abad 21. Social, Humanities, and Education Studies (SHEs): Conference Series, (pp. 48-53). Surakarta.

Hu, Z., He, H., & Guan, C. Z. (2025). Development and influencing factors of artificial intelligence literacy and computational thinking in Chinese university students. Scientific Reports, 1-22.

K.A, N. (2024). Coding Lessons and the Development ofComputational Thinking in Schoolchildren in thePost-Pandemic Educational Landscape: AReview on Research Challenges and Perspectives. RUDN Journal of Psychology and Pedagogics.

Kurniawan, A. W., & Puspitaningtyas, Z. (2016). Metode Penelitian Kuantitatif. Yogyakarta: Pandiva Buku.

Kusuma, N. F., Haerunisa, N., Harahap, A. T., Zainiza, M., Fazira, A., Hastuti, S., . . . Amin, R. (2025). Best Practice Pembelajaran Abad 21. Naba Edukasi Indonesia .

Mahiri, F., Najoua, A., Soueda, S. B., & Amini, N. (2023, April). From Insutry 4.0 to Industry 5.0: The Transition to Human Centricity and Collaborative Hybrid Intelligence. Journal of HUnan University (Natural Scicence), 50(4), 84-94.

Nababan, D., Marpaung, A. K., & Koresy, A. (2023). Strategi Pembelajaran Project Based Learning (PJBL). Pediaqu: Jurnal Pendidikan Sosial dan Humaniora, 2(2), 706-719.

Rafsanjani, A., Amelia, F. A., Dahyanti, N., M. A., & Diastami, S. M. (2023). Pengembangan Profesionalisme Tenaga Kependidikan dalam Mewujudkan Kualitas Pendidikan Islam. Jurnal Pendidikan dan Konseling, 1(1), 2296-2305.

Samsu. (2017). Metode Penelitian: Teori dan Aplikasi Penelitian Kualitatif, Kuantitatif, Mixed Methods, serta Research & Development. Jambi: Pusat Studi Agama dan Kemasyarakatan (PUSAKA).

Sugiyono. (2013). Metode Penelitian Kuantitatif, Kualitatif, dan R & D. Bandung: Alfabeta.

Tariq, R., Babines, B. M., Alvarez-Icaza, I., & Naseer, F. (2024). Computational thinking in STEM education: current state-of-the-art and future research directions. Frontiers in Computer Science, 6, 1-19.

Wekke, I. S. (2019). Metode Penelitian Sosial. Yogyakarta: Penerbit Gawe Buku.

Yusuf, A. M. (2014). Metode Penelitian: Kuantitatif, Kualitatif, Dan Penelitian Gabungan. Jakarta: Kencana.

Yusuf, M. (2017). Metode Penelitian: Kuantitatif, Kualitatif, Dan Penelitian Gabungan. Jakarta: Kencana.