

A Layered Digital Literacy Transformation Model through Coding and Artificial Intelligence at PKBM GEMA

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ABSTRACT

This study aimed to formulate a layered model of digital literacy development through coding and artificial intelligence (AI) learning in equivalency education. A descriptive qualitative study was conducted at PKBM GEMA, Tasikmalaya, from March to June 2026. Seven informants were purposively selected, comprising the PKBM head, an instructor, and school-age and working learners from Packages A, B, and C. Data were generated through semi-structured interviews, learning observations, and document review and analyzed using the interactive model of data condensation, data display, and conclusion drawing with verification. The analysis identified recurring patterns across learners' experiences, learning practices, and learning products, which were organized into five interconnected layers: access and confidence, conceptual understanding, productive skills, critical and ethical practice, and application in learning, work, and entrepreneurship. Rather than representing fixed or strictly sequential stages, the layers describe an interconnected developmental pattern in which access and confidence provide an entry condition, conceptual understanding supports productive practice, productive skills create opportunities for critical and ethical use, and these competencies become meaningful when applied to real-life contexts. The observed development was supported by staged instruction, hands-on practice, projects, mentoring, peer support, and ethical reflection. However, limited devices, unstable internet connectivity, diverse initial competencies, restricted learning time, uneven tutor capacity, and incomplete contextual learning materials constrained continuity. The resulting model therefore provides a qualitative framework for understanding how coding and AI learning can be organized to support differentiated digital literacy development in equivalency education, while its effectiveness and long-term outcomes require further empirical testing.

1. INTRODUCTION

The development of digital technology has changed how people seek information, learn, work, communicate, and make decisions. This change has become more pronounced as artificial intelligence has entered search engines, productivity applications, public services, and workplaces. Wider access creates greater learning opportunities, but it does not automatically produce critical digital competence. The Indonesian Digital Society Index shows that community competence remains a key element of readiness for the digital ecosystem, alongside infrastructure, empowerment, and employment (Pudjianto et al., 2025). This condition requires education to develop the ability to understand information, create products, maintain security, and act responsibly, rather than merely operate devices. Digital literacy should be understood as a life skill that integrates knowledge, skills, critical judgment, and social responsibility. Gilster (1997) places the understanding and evaluation of information at the core of digital literacy. Technological development has subsequently expanded its scope to content production, collaboration, data protection, digital footprints, copyright, and

communication ethics. Therefore, people who are proficient in using digital devices are not necessarily digitally literate. They may access information quickly but may not be able to verify sources, recognize manipulation, protect privacy, or transform information into productive action. Sugiarto and Farid (2023) emphasize the relationship between digital literacy and character formation, particularly honesty, responsibility, and caution in digital spaces. These needs have a particular context in nonformal education. Community Learning Centers (Pusat Kegiatan Belajar Masyarakat, PKBM) serve learners with diverse ages, educational experiences, occupations, motivations, prior competencies, and access to technology. This diversity means that digital learning cannot rely on a single starting standard or a single learning pathway. School-age learners generally recognize application interfaces quickly but still need stronger skills in verification and ethics. Working learners often have clear practical needs but require repetition, flexible schedules, and examples related to their work (Reni Marlina, 2025). Andragogical principles place experience, immediate needs, readiness to learn, and problem solving at the foundation of adult learning (Marlina, Hendriawan, et al., 2026). These principles are relevant for organizing digital activities that value learners' experiences.

Studies of PKBM indicate that learning technology has become an increasingly important issue in nonformal education research. Puspita and Sujarwo (2025) found growing PKBM research related to lifelong learning, empowerment, and digital technology. In equivalency education, digital learning resources can expand access and learning variety when tutors manage them according to learners' needs (Wahidin et al., 2022). A previous study at PKBM GEMA also showed that online learning requires consistent planning, resource organization, monitoring, assessment, and program development (Devi et al., 2023). These findings provide an institutional foundation but do not yet explain how coding and artificial intelligence learning shape layered changes in digital literacy. These findings provide an institutional and pedagogical foundation for technology-supported learning in PKBM. However, they do not yet explain how coding and artificial intelligence can be positioned within an integrated learning process to support the development of digital literacy across learners with different starting points and learning needs. Coding can serve as an educational means of developing systematic thinking. Its learning value extends beyond the ability to write programs. In this study, coding is positioned primarily as a pedagogical tool and learning medium rather than as a standalone technical subject. Its role is to provide structured opportunities for learners to formulate instructions, organize sequences, identify patterns, decompose problems, test procedures, and correct errors. Computational thinking helps individuals simplify problems into components that can be worked on and verified (Shute et al., 2017). Lodi and Martini (2021) emphasize that computational thinking needs to be connected with meaningful concepts, practices, and contexts so that it does not become merely a slogan. Liu et al. (2024) also found in their systematic review that integrating computational thinking requires educator facilitation, planned activities, and opportunities for debugging. Artificial intelligence expands these demands. AI is positioned both as a learning technology and as an object of literacy. As a learning technology, AI provides opportunities for learners to formulate prompts, explore information, generate ideas, and support learning tasks. As an object of literacy, AI requires learners to understand its limitations and critically evaluate accuracy, bias, privacy, attribution, and human responsibility. Users need not only to know how to obtain outputs but also to understand data, patterns, inaccuracies, bias, privacy, and human responsibility.

AI literacy includes the ability to recognize system functions, formulate instructions or prompts, evaluate outputs, compare sources, and make ethical decisions about use (Long & Magerko, 2020; Ng et al., 2021). The UNESCO competency framework places a human-centered orientation, ethics, safety, creativity, and responsibility at the core of learner and educator competencies (Miao et al., 2024; Miao & Cukurova, 2024). Within this framework, artificial intelligence should not be

positioned as an answer-generating machine that replaces the learning process (Saefulmilah et al., 2026). National policy directions provide a basis for coding and artificial intelligence learning through academic papers, implementation guidelines, and learning outcomes. These policies emphasize computational thinking, data literacy, creativity, problem solving, technology safety, and ethics (Indonesia, 2025c, 2025b, 2025a). Learning guidelines also allow internet-based, plugged, and unplugged activities according to the readiness of educational units (Marlina, Awaliyah, et al., 2026). This flexibility aligns with the characteristics of PKBM because the material can be integrated into skills programs, enrichment activities, projects, or thematic learning without waiting for all facilities to be fully available. Nevertheless, research explaining the stages of digital literacy transformation through the combination of coding and artificial intelligence in equivalency education remains limited. Many studies discuss technology use, skills training, or the effects of artificial intelligence separately. Few studies connect device access, conceptual understanding, productive skills, critical assessment, ethics, and application in life as a single developmental process. This gap matters because PKBM learners begin learning from different starting points. Measurements focused only on application mastery may overlook meaningful small changes, such as confidence in using computers, the ability to organize steps, the habit of checking sources, or awareness of data protection (Marlina, Hendriawan, et al., 2026). The model conceptualizes digital literacy development across five interconnected layers: access and confidence, conceptual understanding, productive skills, critical and ethical practice, and application in learning, work, and entrepreneurship. These layers are not assumed to represent rigid or strictly sequential stages; rather, they describe interconnected dimensions of development that may emerge at different rates depending on learners' prior experiences, learning needs, and contextual conditions. The study therefore aims to analyze the learning design, identify the empirical patterns underlying these layers, and examine the conditions that support or constrain their development and continuity.

2. METHODS

This study employed a descriptive qualitative approach to understand the learning process, learner experiences, changes in digital literacy, and institutional conditions in a natural setting. This approach was selected because the primary data consisted of actions, interactions, narratives, work products, documents, and informants' interpretations. The units of analysis comprised three elements: the implementation of coding and artificial intelligence learning; changes in digital knowledge, skills, and ethical attitudes; and program-supporting and inhibiting factors. The study was conducted at PKBM GEMA, Jalan Benda No. 72, Cikalang Village, Tawang District, Tasikmalaya City, West Java, from March to June 2026. The site was purposively selected because it provides Packages A, B, and C and implements coding and artificial intelligence learning as part of its digital skills development program. This setting enabled the study to examine differences in learning experiences among school-age and working learners within the same equivalency education environment. Seven informants were purposively selected based on their direct involvement in the program and their ability to provide information relevant to the research questions. The informants comprised the head of PKBM, one teacher/instructor, and five learners from Packages A, B, and C. Learner selection considered variation in age group, equivalency education level, employment status, prior technology experience, and participation in coding and AI learning. The inclusion criteria for learners were: (1) active enrollment in Packages A, B, or C during the study period; (2) direct participation in coding and/or AI learning activities; (3) sufficient participation to describe their learning experiences; and (4) willingness to participate in interviews and observations. For the school-age and working learner groups, the selection also considered differences in learning needs, technology experience, and

practical application. The PKBM head and instructor were included because of their direct roles in program management, learning implementation, assessment, and pedagogical decision making.

The duration of participants' enrollment in the program and their intensity of participation in coding and AI learning were also considered during informant selection. Prior technology experience was identified through participants' accounts of their previous use of smartphones, computers, internet services, and digital applications. Data were collected through semi-structured in-depth interviews, learning observations, and document review. Interviews were conducted with the seven informants to explore program objectives, participants' initial experiences, learning processes, changes in digital knowledge and skills, ethical practices, and implementation constraints. Each informant was interviewed eight time(s), with each interview lasting approximately thirty minutes. Follow-up interviews were conducted when clarification or confirmation of emerging information was required. Learning observations focused on coding and AI activities conducted during the study period. The observations documented tutor demonstrations, unplugged and plugged activities, device-based practice, tutor and peer support, prompt formulation, AI output checking, error correction, learner interaction, and ethical reflection. Observations were conducted over around twice sessions, with approximately thirty to sixty minutes of observation per session, covering the main learning activities relevant to the research questions. Documents were selected purposively based on their direct relevance to the implementation and assessment of coding and AI learning. The reviewed documents included the institutional profile, relevant national policy documents, teaching materials, worksheets, assessment rubrics, learner portfolios, tutor records, and learner products. Documents were included when they provided evidence concerning learning objectives, learning activities, assessment practices, learner progress, or the use of coding and AI in the program.

Supporting instruments consisted of interview guidelines, observation sheets, document review guidelines, recording devices, field notes, coding matrices, and triangulation matrices. Interview data were transcribed and coded according to informant identity. Analysis followed the interactive model of Miles et al. (2014) through data collection, condensation, display, conclusion drawing, and verification. Condensation was conducted by identifying units of meaning, assigning codes, forming categories, and developing themes. Data were displayed through narratives, selected quotations, thematic tables, and a conceptual model. Data credibility was maintained through source and technique triangulation, member checking, transferability, dependability, and confirmability. Statements from the PKBM head were compared with information from tutors and learners. Interview data were checked against observed behavior and documentary evidence. Information that could potentially lead to misinterpretation was reconfirmed with informants. The researcher maintained an audit trail consisting of guidelines, transcripts, field notes, coding matrices, documents, and analytical memos. The findings were not intended for statistical generalization but for producing contextual explanations and analytical transferability.

Table 1. Informants and Research Data Focus

Code	Position/characteristics	Data focus
KP-01	PKBM Head	Policy, support, evaluation, and program sustainability
GR-01	Teacher/instructor	Strategies, assessment, learner responses, and pedagogical and technical constraints
PA-US-01	Package A, school-age	Initial experience, instructions, basic digital safety, and ethics
PB-US-01	Package B, school-age	Coding logic, digital tasks, account security, and confidence
PB-BK-01	Package B, working	Practical benefits, learning time, devices, and work needs
PC-US-01	Package C, school-age	Use of AI for learning, digital products, and academic ethics

Code	Position/characteristics	Data focus
PC-BK-01	Package C, working	Work/business productivity, data privacy, and AI output evaluation

Source: Research data processed, 2026

3. RESULTS AND DISCUSSION

PKBM GEMA Context and Initial Digital Literacy

PKBM GEMA is a nonformal education unit that provides Packages A, B, and C. Institutional data as of May 1, 2026 recorded 10 study groups, 124 learners, and 27 educators and education personnel. Learners ranged in age from 6 to 43 years. The institution has six classrooms, one computer laboratory, an assembly hall, a management office, a teachers' room, and other supporting facilities. These facilities provide a basic foundation for digital learning, but the number of devices, usage schedules, maintenance, and network stability still require careful management. Learners' initial digital literacy levels were not uniform. School-age learners were generally familiar with smartphones, social media, communication applications, and rapid information searching. This familiarity helped them explore new features, but it was not always accompanied by the ability to verify sources, manage files, protect privacy, or use technology to produce work. Working learners more often connected technology with workplace communication, promotion, record keeping, and practical needs. Some were not yet accustomed to typing, organizing folders, or using productivity applications on computers. The PKBM head positioned the program as part of life skills. Coding was not intended to turn all learners into programmers but to develop precision and systematic thinking. Artificial intelligence was introduced as a support tool that needs to be directed, checked, and used responsibly. This orientation is consistent with the role of PKBM as a space for lifelong learning and empowerment. Puspita and Sujarwo (2025) show that learning technology is an increasingly developed theme in PKBM research, while Tjiptasari and Azizah (2025) emphasize that digital literacy becomes meaningful when it helps learners achieve independence and inclusion.

Staged and Contextual Learning Architecture

Learning planning was differentiated according to level and initial ability. Package A focused on introducing devices, instructions, sequences, patterns, and basic digital safety. Package B developed simple logic, information searching and evaluation, block programming, content creation, and guided use of artificial intelligence. Package C focused on digital projects, information processing, learning and work needs, prompt formulation, output checking, and academic and professional ethics. This division served as an initial pathway rather than a rigid boundary. The tutor reported that hands-on practice, brief examples, and functional tasks were more frequently used than lengthy explanations. During learning activities, learners were asked to organize steps, try prompts, read AI-generated answers, compare information, and revise their results. Errors were treated as part of the learning process. The tutor also described a nonjudgmental learning environment in which learners who were initially hesitant to operate devices or make typing mistakes were encouraged to try and repeat the task. Observation of the learning activities was consistent with these accounts, particularly in the use of demonstrations, guided practice, error correction, and gradual learner participation. These empirical patterns can be interpreted through the concept of scaffolding, in which instructional assistance is adjusted to learners' needs and progressively supports greater independence. In this context, tutor demonstrations and guided practice provided temporary support while learners developed the confidence and ability to perform tasks independently. This interpretation is consistent with Setiyono et al. (2025) and Liu et al. (2024), who emphasize facilitation, practice, and feedback in coding-related learning.

Implementation combined short demonstrations, unplugged activities, hands-on device practice, discussions, group work, simple projects, and individual mentoring. Unplugged activities were used to understand sequences, patterns, decisions, and logic without relying on computers. Plugged activities provided experience in typing, saving files, trying block programming, searching for information, creating content, and using artificial intelligence tools. This combination aligns with national guidelines that allow learning to be adapted to the facilities and readiness of educational units (Astuti et al., 2025). The tutor stated that hands-on practice, brief examples, and functional tasks were more effective than lengthy explanations. Learners were asked to organize steps, try prompts, read answers, compare information, and improve their results. Errors were treated as part of learning. The tutor's nonjudgmental attitude encouraged learners who were initially afraid of pressing buttons or making typing mistakes to try. This activity demonstrates the function of scaffolding, in which assistance is provided according to need and gradually reduced as learners become more independent. These findings support Setiyono et al. (2025) and Liu et al. (2024) regarding the importance of facilitation, practice, and feedback in coding learning. Peer support was an important element. More skilled learners helped peers open applications, type, save documents, or understand instructions. This support accelerated practice while building a sense of safety. However, tutors continued to supervise so that assistance did not become task takeover. Peer learning was effective when helpers explained the steps rather than simply completing the task. This pattern is also relevant to findings from studies of adult digital literacy that position collaboration and inclusive environments as foundations of empowerment (Tjiptasari & Azizah, 2025). Evaluation did not measure only the appearance of the final product. Tutors observed willingness to try, accuracy of steps, ability to explain reasons, level of independence, ways of correcting errors, use of sources, and responsibility in using artificial intelligence. Practical tasks, products, oral explanations, portfolios, and ethical reflections were used together. This approach allowed small developments to be documented proportionally. Redecker (2017) positions the use of digital evidence and feedback as important components of learner empowerment. In the PKBM context, process assessment also prevents learners with low initial ability from being considered unsuccessful merely because their products are not yet polished.

Five Layers of Digital Literacy Transformation

Analysis of interviews, learning observations, learner products, portfolios, and related documents identified recurring patterns across learners' experiences and learning practices. These patterns were grouped into five dimensions that consistently appeared across the data: access and confidence, conceptual understanding, productive skills, critical and ethical practice, and application in life. The five dimensions were subsequently organized into a layered model to represent the observed pattern of digital literacy development at PKBM GEMA. The layers are interpreted as interconnected dimensions rather than rigid stages that every learner must complete sequentially. The data showed differences in learners' strengths and needs across dimensions. For example, a learner could demonstrate productive skills while still requiring support in information verification, whereas another could demonstrate awareness of ethical issues while remaining less confident in operating computers. The model therefore functions as an analytical map for identifying learners' positions, support needs, and evidence of development rather than as a fixed developmental sequence. The first layer is access and confidence. Change begins when learners are willing to use devices, ask questions, repeat steps, and try again after making mistakes. For learners accustomed to using digital devices, access means expanding use from communication applications to computers and productivity applications. For working learners, confidence may be evident in their willingness to type, manage files, or try tools previously considered difficult. This achievement may appear simple, but it becomes a psychological prerequisite for subsequent development. The second layer is conceptual

understanding. The data indicated that learners began to recognize relationships between instructions, sequences, processes, and outcomes. In coding activities, learners practiced organizing steps and identifying incorrect sequences. In AI-related activities, learners learned that outputs depended on the instructions provided and therefore required checking. A working Package C learner stated, “For me, coding learning is not about becoming a programmer but about learning to organize steps. At work, if the steps are not systematic, the result is also chaotic.” The statement illustrates how a learner connected the concept of systematic sequencing with an existing workplace context. This finding suggests that conceptual understanding developed when technical concepts were connected with familiar activities and practical needs. The interpretation is consistent with the use of contextual and meaningful computational thinking practices emphasized by Lodi and Martini (2021).

The third layer is productive skills. Learners demonstrated movement from consuming digital information toward producing documents, posters, presentations, summaries, digital notes, writing outlines, and simple promotional materials. In coding activities, learners practiced breaking tasks into steps, testing procedures, and correcting errors. Similar practices appeared in AI activities when learners formulated prompts, examined the resulting outputs, and revised their instructions. These activities provided empirical evidence that productive digital practices involved repeated cycles of planning, testing, reviewing, and revision. The pattern can be interpreted as an intersection between computational thinking and AI literacy. Coding provides structured opportunities to organize and test processes, while AI-based activities require learners to formulate instructions and evaluate generated outputs (Liu et al., 2024; Ng et al., 2021). The fourth layer is critical and ethical practice. Learners begin to compare sources, check outputs, protect passwords, consider data entered into applications, respect copyright, and avoid copy-and-paste practices. Academic honesty receives particular attention. Learners are asked to reread artificial intelligence outputs, test information, write in their own words, cite sources, and explain the contribution of the tool. This approach is consistent with AI literacy, which emphasizes judgment, transparency, privacy, and human responsibility (Long & Magerko, 2020; Ng et al., 2021). The fifth layer is application in life. Learners use technology to address learning, work, business, communication, record-keeping, or promotional needs. School-age learners connect it with assignments, further study, and information searching. Working learners use it to create documents, develop business ideas, design promotional materials, or improve workplace communication. At this layer, digital literacy becomes part of empowerment. These findings are consistent with nonformal education research showing that digital literacy has an impact when it is connected to productivity, access, participation, and real life (Wahidin et al., 2022).

Table 2. Layered Digital Literacy Transformation Model

Layer	Focus of change	Empirical indicators
1. Access and confidence	Willingness to use devices and try	Opening applications, typing, saving files, asking questions, and repeating practice
2. Conceptual understanding	How technology, data, instructions, algorithms, and AI limitations work	Explaining sequences, cause and effect, data functions, and why AI outputs need to be checked
3. Productive skills	Production of work and problem solving	Creating documents, content, prompts, revisions, and simple solutions
4. Critical and ethical practice	Verification, privacy, security, copyright, and honesty	Comparing sources, protecting data, avoiding copy-and-paste, and acknowledging AI use
5. Application in life	Use of technology for real needs	Learning, working, doing business, communicating, record keeping, and promotion

Source: Research data processed, 2026

Variations in Transformation by Age and Employment Status

Transformation occurs at different rates. School-age learners recognize application icons, menus, and features more quickly. They are willing to explore new tools and readily follow visual examples. However, this speed may be accompanied by habits of seeking instant answers, copying outputs, or ignoring sources. They need tasks that encourage verification, explanation of reasoning, and reflection. Tutors should not only assess whether a task is completed but also examine how information is obtained and processed. Working learners tend to be more cautious and require repetition. Limited time, fatigue, and distance from school experiences affect concentration. Technical terms such as algorithm, prompt, bias, or privacy may seem abstract. However, their motivation increases when examples relate to work, business, administration, or communication. Practical needs become a strong driver. Learners understand the value of sequencing when it is linked to work procedures and understand output verification when it is linked to the risk of inaccurate information. These differences require differentiation without reducing the main objectives. School-age learners can receive challenges to compare sources, explain the use of artificial intelligence, and develop projects. Working learners can receive step-by-step worksheets, short videos, offline materials, additional practice time, and functional tasks. These adjustments are not preferential treatment but the provision of equitable learning opportunities. Uniform activities may instead widen disparities because they benefit only learners who already have devices and prior experience. The variation also shows that transformation is not identical to mastery of the same applications. Measures of success need to consider starting points. For one learner, progress may mean the ability to create a more specific prompt. For another, progress may mean having the confidence to open a computer and save files independently. The layered model helps tutors recognize both changes while maintaining a clear direction of development. Thus, assessment does not become trapped in comparisons among learners but focuses on development and evidence of process.

Supporting Ecosystem, Program Barriers, and Responses

Change was supported by institutional commitment, tutor facilitation, learner interest, task relevance, peer support, a safe learning environment, and the availability of classrooms and a computer laboratory. Management commitment legitimized the program and enabled schedule adjustments. Tutors translated technical terms into simple examples and provided gradual assistance. Tasks related to school, work, or business made the benefits of learning visible. A nonjudgmental atmosphere encouraged learners to try and improve their results. The tutor's role remained central even though technology provides abundant information. This finding is consistent with Rizaldi et al. (2026), who showed that artificial intelligence can enrich materials, but teachers are still needed to filter information, provide explanations, and ensure appropriateness. At PKBM GEMA, tutors also served as a bridge between tools, learner needs, and ethics. Without facilitation, learners may use artificial intelligence to obtain quick answers without understanding the process. Therefore, tutor capacity building needs to cover content, differentiation strategies, assessment, and ethics. The main barriers concerned devices and network access. The number of computers required learners to take turns. Unstable internet connections could interrupt artificial intelligence-based activities and reduce concentration. Some learners did not have adequate devices at home, limiting opportunities to repeat practice. This finding reinforces Wahidin et al. (2022), who noted that digital learning resources require access and management support. Procuring devices is important but insufficient without scheduling, maintenance, offline materials, and fair-use strategies.

Differences in initial ability, technical terminology, and the schedules of working learners also hindered continuity. Overly dense materials made learners easily lose the learning sequence. Rigid schedules reduced attendance and repeated practice. Relevant responses include dividing material into short units, providing printed and digital modules, preparing unplugged activities,

organizing small groups, and offering flexible practice times. The program also requires diagnostic assessment so that tutors know what support should be provided from the beginning. Modules, rubrics, portfolios, and ethical guidelines were not yet fully systematic. Tutors had made adjustments based on experience, but program sustainability requires resources that can be used by more than one person. Modules should contain objectives, steps, examples, exercises, offline alternatives, and reflection. Rubrics should assess understanding, process, product, verification, privacy, attribution, and honesty. Portfolios should store products, work steps, prompt revisions, sources, and reflections so that changes can be traced. These limitations are not a reason to postpone the entire program. Learning can begin through unplugged activities, group use of devices, simple projects, and materials that can be revisited. However, adaptive strategies should not be used to normalize inadequate facilities. The institution still needs to build partnerships, improve connectivity, add devices, and develop tutor competencies. Program responses should proceed along two pathways: optimizing available resources and gradually improving the ecosystem.

Table 3. Barriers and Program Strengthening Responses

Aspect	Empirical barriers	Strengthening response
Devices and internet	Limited computers, shared use, unstable connection	Small groups, laboratory schedules, offline materials, unplugged activities, and facility partnerships
Initial ability	Unequal experience and confidence	Diagnostic assessment, tiered tasks, mentoring, and peer tutoring
Time of working learners	Limited attendance and repeated practice	Flexible schedules, short learning units, printed modules, and reusable videos
Tutor competence	Uneven content, differentiation, assessment, and ethics competencies	Practice-based training, tutor learning communities, and shared teaching resources
Assessment and ethics	Inconsistent rubrics, portfolios, attribution, and AI guidelines	Process portfolios, ethics rubrics, verification records, and transparency in AI use

Source: Research data processed, 2026

Theoretical Contribution and Implications for Nonformal Education

The layered model contributes to digital literacy research by showing that change does not move directly from device access to high-level competence. Access and confidence provide the foundation but are not sufficient. Learners need to understand processes, produce work, apply critical and ethical judgment, and connect technology with life needs. This model extends Gilster's (1997) concept of digital literacy through the integration of computational thinking and AI literacy. Coding provides structure for thinking, while artificial intelligence creates opportunities for question formulation, output evaluation, and reflection on responsibility. Coding and artificial intelligence do not automatically produce digital literacy. Transformation emerges through pedagogical mechanisms such as staged learning, practice, projects, mentoring, collaboration, portfolios, and reflection. These findings reject a deterministic approach that assumes the presence of tools will directly improve learning quality. Technology functions when tutors connect content with context, provide opportunities to try, and establish norms for use. This finding is consistent with Kudriani et al. (2023), who emphasized the importance of pedagogical readiness, ethics, human resources, and infrastructure in digital education transformation. The model also confirms the relationship between digital literacy and empowerment. In equivalency education, program outcomes should not be limited to the ability to complete school assignments. Learners need to use technology for independent learning, work, business, communication, and participation. Application in life is an important layer because it connects competence with expanded choices and independence. This

perspective aligns with the functions of nonformal education as a substitute, supplement, complement, and space for lifelong learning.

4. CONCLUSION

This study identified a contextual, layered pattern of digital literacy development through coding and artificial intelligence learning at PKBM GEMA. Based on the convergence of interview accounts, learning observations, learner products, portfolios, and institutional documents, the findings indicate five interconnected layers: access and confidence, conceptual understanding, productive skills, critical and ethical practice, and application in learning, work, and entrepreneurship. These layers should not be interpreted as empirically measured stages of causal improvement, but as an analytical representation of how learners' experiences and practices were organized across the learning process. The layers were also not strictly linear, as learners entered the program with different levels of prior digital experience and progressed at different paces. The empirical evidence suggests that the five layers were connected through pedagogical processes rather than through the use of technology alone. Initial confidence and willingness to engage with digital devices created a basis for understanding sequences, logic, information, and artificial intelligence. These understandings were subsequently expressed through productive practices such as coding, problem decomposition, prompt formulation, content creation, and iterative error correction. As learners became more engaged with these practices, activities involving source checking, output evaluation, privacy, attribution, and responsible use of artificial intelligence became increasingly relevant. The final layer concerned the contextual application of these practices to learning, work, and entrepreneurial activities. Thus, the model represents a connected learning pathway in which foundational engagement supports conceptual development, concepts are enacted through productive practice, productive practice creates opportunities for critical and ethical judgment, and these competencies are subsequently connected to meaningful real-world applications.

The study contributes a contextual model that brings together digital literacy, computational thinking, AI literacy, and nonformal education within a single analytical framework. Its contribution lies not in demonstrating that coding or artificial intelligence independently causes digital literacy improvement, but in identifying the pedagogical and contextual mechanisms through which these learning experiences can facilitate the development of interconnected digital competencies. The evidence points to staged instruction, hands-on practice, unplugged and plugged activities, mentoring, peer support, project-based tasks, portfolio documentation, and ethical reflection as important elements connecting the layers. Institutional support, task relevance, a supportive learning environment, and basic technological facilities further shaped the continuity of this process. For practice, PKBM programs can use the layered model as a flexible planning framework rather than as a rigid sequence. Learning pathways may be differentiated across Packages A, B, and C according to learners' prior experience, learning needs, and intended applications. Assessment should capture not only final products but also learning processes, problem-solving steps, source verification, prompt use, privacy awareness, attribution, and responsibility for AI-assisted outputs. Strengthening tutor capacity, developing contextual and reusable learning materials, improving access to devices and connectivity, and establishing partnerships may further support implementation. The findings should be interpreted in light of the study's qualitative and contextual scope.

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