

The TPL-DC Model: Generative AI-Enhanced Personalized Training for Teachers' Digital Competency

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Abstract

The rapid advancement of generative artificial intelligence (AI) has intensified the need for teaching professional development models that move beyond tool-level training toward adaptive, competency-oriented learning environments. This study aims to design, develop, and validate the TPL-DC Model (Training Personalized Learning for Digital Competency Development), a design-oriented framework that integrates structured training processes, personalized learning principles, and generative AI-enhanced instructional mechanisms to support future-ready teacher digital competency development. Employing a research and development (R&D) methodology, the study synthesizes theoretical foundations across four domains: training learning systems, personalized learning, generative AI in training, and digital competency frameworks. The synthesis resulted in a unified seven-stage Training Personalized Learning Process, within which generative AI functions, such as learner analytics, adaptive content generation, intelligent recommendations, and continuous monitoring, are systematically embedded across all stages of the training cycle. The model operationalizes digital competency development across five core domains: information and data literacy, digital content creation, communication and collaboration with AI, problem solving and innovation, and safety and ethics. Model validation was conducted through expert evaluation involving seven specialists in educational technology and AI in education. The results indicate a high level of conceptual coherence, structural appropriateness, and practical feasibility, with an overall mean rating of 4.88 out of 5.00. The findings suggest that the TPL-DC Model provides a theoretically grounded, scalable blueprint for designing AI-enhanced teacher-training environments. Rather than focusing on effectiveness testing, this study contributes a process-level, AI-embedded training architecture that advances personalized, data-driven, and sustainable teacher professional learning in AI-mediated educational ecosystems.

Keywords: teacher training, generative artificial intelligence, personalized learning, digital competency, training model design

1. Introduction

The rapid advancement of generative artificial intelligence (AI) is reshaping educational systems worldwide, creating new opportunities and challenges for teacher professional development. As schools increasingly integrate intelligent technologies into instructional practice, teachers are expected to develop advanced digital competencies, including data literacy, AI-mediated communication, adaptive content creation, and ethical technology use (Ng et al., 2023; Mejias-Acosta et al., 2024). These emerging expectations require training environments that equip teachers with

technical skills and support personalized, flexible, and data-driven learning pathways. Traditional training models, however, often lack the adaptivity and individualized support necessary to address diverse teacher needs in AI-enhanced settings. At the same time, personalized learning has gained prominence as a framework for tailoring instruction to individual learner profiles. Contemporary literature emphasizes processes such as learner profiling, personal goal setting, personalized learning pathway design, and continuous adaptation supported by technology-enhanced analytics (Sharples, 2023; Yu & Guo, 2023). While these approaches have been widely applied in student learning contexts, their systematic integration into teacher training remains underdeveloped. Bridging this gap requires combining structured training processes with personalization mechanisms that respond dynamically to teacher characteristics and professional growth trajectories.

Generative AI technologies offer transformative potential in this regard. Recent studies highlight the capacity of AI systems to automate content creation, generate adaptive learning resources, provide real-time feedback, and optimize instructional pathways through machine learning–based recommendations (Zawacki-Richter et al., 2019; Chen et al., 2022). Integrating these tools into teacher-training environments introduces new possibilities for scalable personalization, continuous performance monitoring, and targeted competency development. However, the field lacks a coherent, evidence-based model that unifies training design principles, personalized learning processes, and AI-enhanced instructional support. To address this gap, the present study aims to design, develop, and validate the TPL-DC Model (Training Personalized Learning for Digital Competency Development), a comprehensive framework for AI-enhanced teacher training grounded in synthesized theoretical foundations. By integrating the seven-phase Training Learning Process with the six-component Personalized Learning Process, the study constructs a unified Training Personalized Learning Process that serves as the core structure of the TPL-DC Model. This model further incorporates generative AI tools into each stage of the training cycle, enabling adaptive content generation, personalized pathway optimization, and continuous learner monitoring. The resulting system aligns with digital competency domains essential to contemporary teaching practice, including information and data literacy, communication and collaboration with AI, digital content creation, problem-solving, and digital ethics. The effectiveness of the model was examined through expert evaluation, which demonstrated high levels of conceptual soundness, structural coherence, and practical applicability, with an overall mean evaluation score of 4.88 out of 5.00

These findings indicate that the TPL-DC Model provides a theoretically robust and practically feasible framework for designing AI-enhanced teacher training environments. In summary, integrating generative AI, personalized learning principles, and structured training processes offers a promising direction for advancing teacher digital competency development. This study contributes to the field by providing a validated, scalable model that supports adaptive, data-driven, and future-ready teacher professional learning. Accordingly, this study adopts a design-oriented research and development (R&D) approach rather than focusing on effectiveness testing.

2. Literature Review

Training learning systems provide the structural foundation for organizing professional development processes. These systems typically include phases such as needs analysis, curriculum design, content development, instructional delivery, assessment, and evaluation.: Training Learning Systems, Personalized Learning, Generative AI in Training, and Digital Competency Frameworks. These domains collectively provide conceptual grounding for the TPL-DC Model and clarify how structured training principles, learner-centered adaptivity, and AI-driven technologies converge to support teacher professional development.

2.1 Training Learning Systems

The development of AI-enhanced training environments requires a coherent theoretical foundation grounded in four major domains: Training Learning Systems, Personalized Learning, Generative AI in Training, and Digital Competency Frameworks. These domains collectively provide conceptual grounding for the TPL-DC Model and clarify how structured training principles, learner-centered adaptivity, and AI-driven technologies converge to support teacher professional development.

2.2 Personalized Learning

Personalized Learning represents a theoretical shift from uniform instructional approaches to adaptive systems that tailor learning trajectories to individual characteristics. Foundational theories conceptualize personalization as an interplay between learner profiling, personal goal construction, adaptive content pathways, and continuous data-driven refinement (Sharples, 2023; Yu & Guo, 2023). Personalized learning frameworks emphasize three theoretical pillars:

1. Learner Modeling: understanding prior knowledge, preferences, and performance patterns.
2. Adaptive Pathway Design dynamically aligning content, pacing, and modality with learner needs.
3. Iterative Feedback Systems using real-time performance data to refine learning sequences.

These theories provide the basis for integrating adaptive mechanisms within structured training systems.

2.3 Generative AI in Training

Generative AI introduces new theoretical capabilities for instructional automation and adaptivity. Contemporary research identifies AI as an enabler of three primary functions in training environments: (1) intelligent learner analytics, capable of identifying patterns from multi-source data; (2) automated content generation, producing multimodal instructional materials aligned with learner profiles; and (3) adaptive recommendation systems, optimizing learning pathways through machine-learning models (Zawacki-Richter et al., 2019; Chen et al., 2022). Within professional learning contexts, generative AI theory emphasizes human-AI collaboration, where AI functions as an augmentation mechanism that enhances instructional personalization and expands teachers' access to real-time feedback and adaptive resources. These capabilities provide the technological foundation for embedding AI across the TPL-DC training stages.

2.4 Digital Competency Frameworks

Digital competency frameworks define the knowledge, skills, and attitudes necessary for effective participation in AI-mediated learning ecosystems. Contemporary frameworks such as DigComp, AI Competency Standards, and education-specific digital literacy models highlight core domains including information and data literacy, AI-mediated communication and collaboration, digital content creation, problem-solving, and ethical technology use (Mejías-Acosta et al., 2024; Ng et al., 2023). Theoretical discussions emphasize that digital competence is developmental, iterative, and context-dependent; thus, training systems must offer opportunities for ongoing skill refinement. These frameworks inform the competency outcomes embedded within the TPL-DC Model and guide the alignment of training content with required digital skills.

3. Method

This study employed a Research and Development (R&D) methodology with a specific focus on synthesizing theoretical foundations to construct and validate the TPL-DC Model. In line with the study's aims, the method section emphasizes the procedures used to analyze the literature, integrate theoretical constructs, and validate the model, without reiterating the conceptual content presented in the Literature Review or Results sections.

3.1 Phase 1: Theoretical and Empirical Synthesis

This phase involved systematic documentary research using purposive selection of scholarly sources across four theoretical domains: training learning systems, personalized learning, generative AI in training, and digital competency frameworks. The synthesis procedure included:

1. Identifying relevant high-quality literature.
2. Extracting core principles, models, and theoretical constructs.
3. Comparing and contrasting frameworks to identify convergences.
4. Organizing extracted elements into structured conceptual categories.

The output of this phase was a set of theoretical components serving as the foundation for subsequent model construction.

3.2 Phase 2: Integrative Model Construction

The second phase translated and synthesized theoretical components into an integrated Training Personalized Learning framework. The synthesis procedure comprised:

1. Mapping parallel components across the four domains.
2. Establishing alignment rules to merge training processes with personalized learning principles.
3. Identifying AI-enhanced mechanisms that operationalize adaptivity within each stage; and
4. Structuring these integrated components into a coherent, iterative model.

This phase produced the initial design of the TPL-DC Model.

3.3 Phase 3: Expert Validation

A structured expert review was conducted to assess conceptual validity and practical feasibility. The validation procedure included:

1. Selecting seven experts in educational technology and AI in education.

The expert panel consisted of seven specialists selected through purposive sampling based on the following criteria:

- 1) A doctoral degree in Educational Technology, Artificial Intelligence in Education, or related fields
 - 2) At least five years of experience in teacher training or digital competency development
 - 3) Prior research publications related to AI in education or educational technology
 - 4) Experience in curriculum design or professional development programs for teachers
2. Using a standardized Likert-scale evaluation form assessing conceptual integration, structural appropriateness, and digital competency alignment
 3. Analyzing responses through descriptive statistics
 4. Refining the model based on expert feedback.

This process ensured the reliability and suitability of the TPL-DC Model for implementation.

3.4 Ethical Considerations

The study adhered to academic integrity standards, ensured the absence of personal data collection, and followed responsible AI adoption principles across all phases.

4. Results

4.1 Synthesis of TPL-DC Model

4.1.1 Training Learning Process

The Training Learning Process encompasses a comprehensive framework consisting of seven interconnected phases that guide effective instructional design and implementation. This synthesis examines how various scholars have addressed different components of this process, revealing patterns of emphasis and gaps in the literature.

Table 1. Synthesis of Training Learning Process Steps in Previous Studies

Training Learning Process	Training Needs Analysis	Curriculum Design	Content Development	Instructional Strategy & Tools	Assessment Design	Training Delivery	Evaluation & Revision
Trandafir et al. (2008)	x	x	x		x	x	x
Blagoev et al. (2019)	x	x	x	x		x	x
Omar et al. (2024)	x		x	x	x	x	
Ray et al. (2014)	x		x	x	x	x	x
Ivanova (2022)	x	x	x	x	x	x	
Howlin & Lynch (2014)	x	x	x	x	x		x
Grigoriadou & Papanikolaou (2006)		x	x	x	x	x	
Okoye (2019)	x	x	x		x	x	

Table 1. Synthesizes seven essential phases of the Training Learning Process and illustrates how prior studies conceptualize the design and implementation of effective training systems. The analysis shows that Training Needs Analysis is the most consistently emphasized phase, serving as the analytical foundation for identifying learner gaps and contextual requirements (Trandafir et al., 2008; Ray et al., 2014). Building on this foundation, Curriculum Design ensures that learning objectives, content scope, and instructional sequencing are aligned with identified needs, a point reinforced by Blagoev et al. (2019) and Howlin and Lynch (2014).

The synthesis further highlights extensive attention to Content Development, reflecting its centrality in shaping learning relevance and instructional quality (Omar et al., 2024; Ivanova, 2022). Similarly, studies addressing Instructional Strategy and Tools emphasize the strategic integration of pedagogical methods and technological resources to enhance adaptability and learner engagement. Assessment Design appears as a critical mechanism for measuring learning progress and ensuring alignment between instructional intentions and learner performance (Okoye, 2019). The phases of Training Delivery and Evaluation & Revision collectively underscore the importance of effective implementation and continuous improvement, positioning training as a dynamic, evidence-informed process. Collectively, the synthesis demonstrates a coherent, iterative model in which each phase contributes to a comprehensive and adaptive training ecosystem.

4.1.2 Personalized Learning Process

The Personalized Learning Process represents a paradigmatic shift from traditional one-size-fits-all educational approaches toward individualized, adaptive learning systems that accommodate diverse learner characteristics and preferences. This synthesis examines how contemporary scholars have conceptualized and implemented the six core components of personalized learning, revealing both convergent themes and distinctive approaches within the current literature.

Table 2. Components of Personalized Learning Process Identified in the Literature

Personalized Learning	Learner Profiling	Personal Goal Setting	Personalized Learning Pathway Design	Content and Instructional Adaptation	Technology-Enhanced Personalization	Continuous Assessment & Adaptation
Sharples (2023)	x		x	x	x	
Ng et al. (2023)	x	x	x	x	x	
Hutson & Ceballos (2023)		x	x	x	x	x
Mallik & Gangopadhyay (2023)	x		x	x	x	x
Baskara (2023)		x	x	x		x
Yu & Guo (2023)	x	x	x	x	x	x

Table 2 synthesizes contemporary perspectives on personalized learning by highlighting six core components that collectively shape adaptive, learner-centered educational environments. The analysis demonstrates strong scholarly convergence on learner profiling, which is consistently emphasized as the foundational step for systematically identifying learners’ prior knowledge, cognitive patterns, and preferences (Sharples, 2023; Ng et al., 2023). Building on this foundation, personal goal setting supports learner agency by aligning individual motivations with structured learning expectations, although this component receives comparatively moderate emphasis across studies (Hutson & Ceballos, 2023).

A key area of consensus concerns personalized learning pathway design, which is widely recognized as essential for structuring adaptive sequences that respond to learner diversity (Mallik & Gangopadhyay, 2023). Content and instructional adaptation emerge as the most universally represented components, underscoring their central role in ensuring real-time responsiveness to learner progress and engagement (Baskara, 2023). The table also highlights the growing influence of technology-enhanced personalization, where AI-driven analytics, recommendation systems, and adaptive algorithms enable scalable personalization (Yu & Guo, 2023; Kamalov et al., 2023). Finally, continuous assessment and adaptation function as the system’s feedback loop, allowing dynamic refinement of learning trajectories based on ongoing learner performance. Collectively, the synthesis shows that personalized learning requires an integrated, data-driven ecosystem in which pedagogical design and AI-enhanced technologies co-evolve

to support meaningful, individualized learning experiences.

4.1.3 Training Learning Process integrates Personalized Learning Process

The individualized training process represents a systematic approach to personalized learning that addresses the diverse needs, preferences, and capabilities of individual learners. This framework integrates contemporary educational theories with practical implementation strategies to create effective, learner-centered training environments.

Table 3. Integration of Training Learning Process and Personalized Learning Process

Training Content Development Process	Personalized Learning	Training Personalized Learning Process
1. Training Needs Analysis	1. Learner Profiling	1. Individual Learner Analysis
2. Curriculum Design	2. Personal Goal Setting	2. Personalized Goal Setting and Learning Pathway Design
3.(Content Development)	3. Personalized Learning Pathway Design	3. Individualized Content and Activity Design
4. Instructional Strategy & Tools	4. Content and Instructional Adaptation	4. Strategic Training Method and Tool Selection
5.(Assessment Design)	5. Technology-Enhanced Personalization	5. Technology-Enhanced Personalization Implementation
6. Training Delivery	6. Continuous Assessment & Adaptation	6. Training Implementation with Continuous Monitoring and Adaptation
7. (Evaluation & Revision)		7. Training Evaluation and Future Development

Table 3 illustrates the systematic integration between the conventional Training Learning Process and the Personalized Learning Process, demonstrating a coherent alignment of instructional design principles with individualized learning approaches. The synthesis clarifies how each stage of the training cycle is enhanced through personalization mechanisms, creating more adaptive, learner-centered training environments.

The integration begins with aligning the Training Needs Analysis and Learner Profiling, forming a comprehensive Individual Learner Analysis. This fusion ensures that organizational training requirements are complemented by in-depth learner data, enabling more accurate identification of competency gaps (Sharples, 2023; Ng et al., 2023). Subsequently, Curriculum Design is merged with Personal Goal Setting and Personalized Learning Pathway Design, resulting in a unified stage of Personalized Goal Setting and Pathway Design. This step enhances learner motivation and ensures that training pathways align with both institutional objectives and individual aspirations (Hutson & Ceballos, 2023).

The traditional Content Development phase is reinterpreted through personalization principles, resulting in Individualized Content and Activity Design that supports adaptive materials responsive to learner performance patterns (Mallik & Gangopadhyay, 2023). Similarly, the Instructional Strategy & Tools component integrates with Content and Instructional Adaptation, forming a stage centered on strategic, individualized selection of methods and tools (Kamalov et al., 2023).

Technology plays a crucial bridging role: Assessment Design and Technology-Enhanced Personalization converge to support data-driven personalization and targeted interventions (Yu & Guo, 2023). During Training Delivery, the integration with Continuous Assessment & Adaptation enables real-time adjustments to instructional pathways based on learner progress and engagement (Sharples, 2023). Finally, the combination of Evaluation & Revision with personalized learning’s adaptive mechanisms forms a comprehensive stage of Training Evaluation and Future Development, enabling iterative improvement and long-term personalization of training programs. The table demonstrates that integrating training and personalized learning processes results in a dynamic, adaptive system capable of delivering individualized learning experiences while maintaining coherence with organizational training goals.

4.1.4 AI-Enhanced Training Personalized Learning Process: Digital Competency Development Framework

The integration of generative artificial intelligence (AI) tools into personalized learning frameworks represents a significant shift in digital competency development. AI enables adaptive learning environments that support individualized teacher training pathways. This synthesis examines how contemporary AI technologies can be systematically embedded within each stage of the Training Personalized Learning Process to enhance digital literacy and competency acquisition.

Table 4. Integration of Generative AI Tools with the Training Personalized Learning Process

Integration of Training Personalized Learning Process with Generative AI Tools and Digital Competency			
Training Personalized Learning Process	Generative AI Tools	Digital Competency	References
1. Individual Learner Analysis	AI-powered learner analytics and assessment tools for comprehensive learner profiling and competency gap identification	Competency in data interpretation and analytics-based decision making in educational contexts	Zawacki-Richter et al. (2019)
2. Goal Setting and Personalized Learning Pathway Design	AI-driven content recommendation systems, SMART goal setting platforms, and automated learning path optimization	Advanced competency in educational technology integration and strategic learning design	Chen et al. (2022)
3. Content Development and Instructional Design for Individualized Training	AI-assisted content creation, automated learning object generation, and adaptive instructional material development	Content creation competency using digital tools and multimedia integration skills	Omar et al. (2024)
4. Training Strategy and Tool Selection for Individual Learners	Intelligent tutoring systems, AI-powered chatbots, and personalized learning management platforms	Strategic competency in educational technology selection and implementation	Winkler & Söllner (2018)
5. Technology-Enhanced Personalized Learning Implementation	Generative AI for personalized content delivery, recommendation engines, and adaptive learning analytics	Advanced digital literacy and competency in emerging educational technologies	Ouyang & Jiao (2021)
6. Training Implementation with Continuous Monitoring and Adaptation	AI-driven learning analytics, real-time assessment tools, and automated feedback systems	Competency in data-driven decision-making and continuous improvement methodologies	Alam, A. (2021)
7. Training Evaluation and Future Development of Individualized Learning	AI-powered assessment analytics, predictive modeling for learning outcomes, and automated reporting systems	Evaluation of competency and competency in evidence-based educational improvement	Ouyang & Jiao (2021)

Stage 1: AI-Powered Individual Learner Analysis

Implementing AI-driven learner analysis involves sophisticated data collection and processing beyond traditional assessment methods. Zawacki-Richter et al. (2019) demonstrate how AI systems can analyze multiple data streams, including learning behaviors, content interactions, and performance patterns, to create comprehensive learner profiles. These AI-enhanced profiling systems enable the identification of individual digital competency gaps, learning preferences, and optimal skill-development pathways, providing unprecedented granularity in learner characterization.

Stage 2: Intelligent Goal Setting and Pathway Optimization

AI technologies facilitate dynamic goal setting through predictive analytics and personalized recommendation systems. Chen et al. (2022) illustrate how machine learning algorithms can analyze individual competency baselines and organizational requirements to generate optimal learning objectives and pathways. The integration of SMART

goal frameworks with AI-driven analytics ensures that personalized learning objectives remain achievable while also challenging learners to develop essential digital competencies systematically.

Stage 3: Adaptive Content and Activity Generation

The deployment of AI for content creation and activity design represents a significant advancement in the implementation of personalized learning. Omar et al. (2024) demonstrate how generative AI systems can create customized learning materials that adapt to individual proficiency levels and learning styles. These systems can generate diverse content formats, interactive exercises, and assessment activities that align with specific digital competency development objectives while maintaining pedagogical coherence.

Stage 4: Intelligent Strategy and Tool Selection

AI-enhanced selection of training methodologies involves sophisticated matching algorithms that align instructional strategies with learner characteristics and competency development goals. Winkler & Söllner (2018) emphasize how intelligent systems can recommend optimal combinations of learning modalities, technological tools, and instructional approaches based on individual learner profiles and performance data. This includes the strategic integration of chatbots, virtual assistants, and other AI tools that provide personalized learning support.

Stage 5: Technology-Enhanced Personalization Infrastructure

The implementation of comprehensive AI-driven personalization requires a robust technological infrastructure capable of real-time data processing and adaptive response generation. Ouyang & Jiao (2021) highlight how AI systems can provide continuous recommendations, adaptive content delivery, and personalized feedback, thereby supporting ongoing digital competency development. This infrastructure enables seamless integration of various AI tools within cohesive learning environments.

Stage 6: Continuous Monitoring and Adaptive Support

AI-powered training delivery involves sophisticated monitoring systems that track learner progress, engagement patterns, and competency development in real-time. Alam, A. (2021) demonstrate how intelligent systems can provide immediate feedback, adaptive content adjustments, and personalized support interventions that optimize learning outcomes. These systems enable proactive identification of learning challenges and automatic deployment of remedial strategies.

Stage 7: Intelligent Evaluation and Continuous Improvement

The evaluation phase leverages AI analytics to assess both individual learning outcomes and system effectiveness. Ouyang & Jiao (2021) illustrates how machine learning algorithms can analyze comprehensive learning data to identify patterns, predict future performance, and recommend system improvements. This enables continuous refinement of both individual learning pathways and the overall personalized learning framework.

4.1.5 Digital Competency

Table 5. Synthesis of Digital Competency Components

Digital Competency	Component Digital Competency		
	Information & Data Literacy	Digital Content Creation	Communication & Collaboration with AI
Falloon (2020)	x	x	x
Reisoglu (2021)	x	x	x
Choudhary & Bansal (2022)	x	x	x
Rachbauer et al. (2025)	x	x	x
Silber-Varod et al. (2019)	x	x	x

Table 5. Synthesizes contemporary scholarship to illustrate how digital competency is conceptualized across three core components essential for AI-enhanced teacher development: Information and Data Literacy, Digital Content Creation, and Communication and Collaboration with AI. The reviewed studies consistently highlight Information and Data Literacy as a foundational element, emphasizing teachers’ capacity to locate, evaluate, and interpret digital information in data-rich learning environments. Falloon (2020), Reisoglu (2021), and Choudhary and Bansal (2022) argue that such literacy is critical for informed pedagogical decision-making, particularly as educational systems

increasingly rely on data analytics and algorithmic feedback. The second domain, Digital Content Creation, reflects a shift toward more active forms of digital engagement. Scholars such as Silber-Varod, Eshet, and Geri (2019) and Rachbauer et al. (2025) emphasize that teachers must be able to design, modify, and integrate multimodal digital resources that support diverse learner needs. This competency aligns with the growing demand for educators to produce adaptive and interactive instructional materials that can be integrated into AI-supported learning systems.

The third domain, Communication and Collaboration with AI, captures emerging competencies associated with human–AI interaction. Falloon (2020) and Reisoglu (2021) highlight the growing role of AI-mediated communication tools that assist teachers in generating feedback, supporting decision-making, and facilitating collaborative learning. Such competencies reflect broader shifts in digital pedagogy, where educators must be prepared to work alongside AI systems as instructional partners. Taken together, the table demonstrates apparent convergence across studies on the multidimensional nature of digital competency. These findings validate the competency framework embedded in the TPL-DC Model and underscore its alignment with current educational and technological demands.

4.2 Results of Development TPL-DC Model

The presented circular model serves as a comprehensive framework for digital competency development, integrating contemporary educational methodologies with emerging technological capabilities. This model demonstrates the systematic integration of seven sequential stages within a cohesive learning ecosystem designed to enhance digital literacy through personalized, technology-enhanced training approaches.



Figure 1. TPL-DC Model

Figure 1. Presents the TPL-DC Model, a comprehensive framework designed to support systematic digital competency development through technology-enhanced, personalized training processes. The circular structure reflects the model's iterative and continuous nature, emphasizing that digital competency is not acquired through linear progression but through cyclical engagement with learning, feedback, and refinement. At its core, the model integrates principles of personalized learning, AI-supported training, and competency-based education, aligning them within a unified instructional ecosystem (Sharples, 2023; Ng et al., 2023).

Part 1: External Support Infrastructure and Initial Engagement

The outermost layer of this model establishes the foundational support mechanisms essential for sustainable teacher professional development. Teachers Receive Training serves as the primary entry point, where educators engage with structured professional development programs designed to enhance their technological and pedagogical competencies (Darling-Hammond et al., 2017). This initial engagement is critical, as research demonstrates that

practical teacher training requires sustained, content-focused professional development rather than one-time workshops (Desimone & Pak, 2017). The Learning Infrastructure component provides the technological backbone, institutional policies, and resource allocation necessary to support continuous professional development (Trust et al., 2020). Contemporary studies emphasize that successful technology integration depends heavily on institutional commitment to providing adequate hardware, software, connectivity, and technical support systems (Ertmer et al., 2012). The Generative AI Tools/Platforms external component represents the emerging technological ecosystem, including ChatGPT, Claude, Gemini, and other large language models, that is transforming educational practices globally (Kasneji et al., 2023; Zhai et al., 2024). These platforms serve as both training objects and pedagogical partners, fundamentally reshaping how teachers conceptualize content creation, assessment design, and the delivery of personalized learning (Baidoo-Anu & Ansah, 2023). The bidirectional arrows connecting these external elements indicate dynamic feedback loops where training outcomes inform infrastructure development, and technological advancements continuously reshape training content and methodologies, reflecting the iterative nature of educational technology adoption (Venkatesh et al., 2012).

Part 2: Seven Interconnected Training Environment Components Leading to Competency Development

Moving inward, the model presents seven systematically sequenced components that constitute a comprehensive training environment. Component 1) Digital Literacy Training establishes foundational competencies in technology navigation, digital tool proficiency, and basic computational thinking skills essential for subsequent AI integration (Ng, 2012; Falloon, 2020). Research confirms that without adequate digital literacy foundations, teachers struggle to effectively implement advanced technologies in their pedagogical practices (Redecker, 2017). Component 2) Critical Thinking and Problem-Solving develops higher-order cognitive skills necessary to evaluate AI-generated content, identify algorithmic biases, and make informed pedagogical decisions regarding technology use (Sullivan & Leung, 2023). Studies demonstrate that critical evaluation of AI outputs is essential to prevent the propagation of misinformation and ensure educational quality (Rudolph et al., 2023). Component 3) Continuous Assessment and Constructive Feedback implements formative evaluation mechanisms that monitor learning progression and provide actionable guidance throughout the training process (Hattie & Timperley, 2007; Shute, 2008). Evidence indicates that continuous feedback loops significantly enhance professional development outcomes by enabling real-time adjustment of learning strategies (Van der Kleij et al., 2015).

Component 4) Generative AI Tools/Platforms introduces educators to specific AI technologies through hands-on practice, experimentation, and pedagogical application (Becker et al., 2023; Chan & Hu, 2023). Research shows that authentic engagement with AI tools in educational contexts promotes a more profound understanding of their affordances and limitations (Celik et al., 2024). Component 5) Training Content delivers structured curriculum modules addressing instructional design with AI, ethical considerations, prompt engineering, and assessment redesign in the age of generative AI (Sullivan et al., 2023; Wardat et al., 2024). Studies emphasize that contextually grounded, practice-based professional development yields superior outcomes compared to generic technology training (Koehler & Mishra, 2009). Component 6) Training Implementation with Continuous Support, Monitoring, and Adaptation ensures sustained professional development through ongoing mentorship, communities of practice, and responsive program modifications based on participant feedback and emerging needs (Borko et al., 2010; Voogt et al., 2013). Research confirms that continuous support structures are critical for translating training into classroom practice and preventing professional development decay (Desimone, 2009). Component 7) returns to Learning Infrastructure, creating a cyclical connection that underscores the need for infrastructural elements to continuously evolve to support advancing competencies and emerging technologies (Fullan & Langworthy, 2014).

The results of this seven-component training environment are demonstrable improvements in teacher self-efficacy with technology (Tschannen-Moran & Hoy, 2001), enhanced technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006), and measurable changes in instructional practices that integrate AI tools for personalized learning, differentiated instruction, and efficient assessment design (Crompton & Burke, 2023; Ouyang & Jiao, 2021).

Part 3: Core Outcome - Digital Competency as Multidimensional Capability

At the center of this model resides Digital Competency, the outcome of the systematic training process, manifesting as four interconnected dimensions. Digital Literacy and Data Literacy represent educators' capacity to navigate digital environments, interpret datasets, utilize learning analytics, and make evidence-based instructional decisions (Pangrazio & Sefton-Green, 2020; Mandinach & Gummer, 2016). Research demonstrates that data-literate teachers significantly improve student outcomes through targeted interventions informed by assessment analytics (Marsh, 2012). Communication and Collaboration Skills encompass digital communication proficiency, online community

engagement, and collaborative work in distributed environments, competencies essential for modern professional learning networks and virtual team teaching (Lantz-Andersson et al., 2018; Trust et al., 2016). Studies confirm that digitally collaborative teachers demonstrate higher rates of innovation adoption and sustained professional growth (Prestridge, 2019).

Digital Content Creation empowers educators to design, develop, curate, and adapt multimedia learning resources, interactive assessments, and AI-enhanced instructional materials that engage contemporary learners across diverse modalities (Mishra et al., 2013; Kimmons, 2015). Evidence indicates that teachers proficient in digital content creation facilitate deeper student engagement and improved learning outcomes through varied representational formats (Bower, 2017). Information, Data, and Media Literacy enable critical evaluation of digital information sources, recognition of misinformation, understanding of algorithmic systems, and ethical data practices increasingly vital competencies in AI-saturated educational environments (McGrew et al., 2018; Wineburg & McGrew, 2019). Research demonstrates that media-literate teachers are better equipped to foster similar competencies in students, creating ripple effects throughout educational systems (Hobbs, 2017).

The outcomes achieved through developed digital competency are substantial: teachers demonstrate increased confidence in technology integration (Scherer et al., 2019), implement more innovative pedagogical approaches (Tondeur et al., 2017), create personalized learning environments leveraging AI capabilities (Holmes et al., 2019), and serve as effective models of digital citizenship for students (Ribble, 2015). Meta-analytic evidence confirms that teachers with comprehensive digital competencies achieve significantly higher student achievement in technology-rich learning environments than those with limited digital capabilities (Schmid et al., 2014; Sung et al., 2016). Furthermore, digitally competent teachers report higher job satisfaction, greater professional efficacy, and sustained engagement with continuous professional development (Admiraal et al., 2017), creating virtuous cycles of educational improvement.

This inside-out architecture demonstrates how systematic, multi-layered professional development environments produce transformative outcomes, equipping educators not merely with tool proficiency but with comprehensive digital competencies that fundamentally enhance their professional practice and student learning outcomes in increasingly technology-mediated educational landscapes (Zhao et al., 2021; European Commission, 2020).

Model, without reiterating the conceptual content presented in the Literature Review or Results sections.

4.3 The Results of an Expert Evaluation of the TPL-DC Model

Table 6. Expert Evaluation of TPL-DC Model

Evaluation list	Evaluation results		Suitability
	Mean	S.D.	
1. Conceptual Framework for Design and Development of TPL-DC Model			
1.1 To what extent is the conceptual framework for design and development of the TPL-DC Model appropriate?	5.00	0.00	Most
1.2 To what extent is the integration of model components (Conceptual Integration) appropriate?	5.00	0.00	Most
1.3 To what extent is the practical applicability appropriate?	4.86	0.38	Most
2. Appropriateness of TPL-DC Model Components for AI-Enhanced Teacher Training Environment			
1. To what extent is the structural appropriateness of components appropriate?	5.00	0.00	Most
2. To what extent is the appropriateness of AI integration with training processes (AI Integration Appropriateness) appropriate?	5.00	0.00	Most
3. To what extent is the appropriateness for practical implementation in educational environments (Practical Relevance) appropriate?	4.71	0.49	Most
3. Training Process and Personalized Learning Process (Training & Personalized Learning Process)			
1. To what extent is the individual learner analysis appropriate?	4.71	0.49	Most
2. To what extent is the personal goal setting and learning pathway design appropriate?	4.86	0.38	Most
3. To what extent is the individualized content and activity design appropriate?	4.71	0.49	Most

Evaluation list	Evaluation results		Suitability
1. Conceptual Framework for Design and Development of TPL-DC Model	Mean	S.D.	
4. To what extent are the strategic training methods and tool selection appropriate?	4.71	0.49	Most
5. To what extent is the implementation of technology-enhanced personalized customization appropriate?	4.86	0.38	Most
6. To what extent is continuous monitoring and adaptive training appropriate?	4.86	0.38	Most
7. To what extent are the training evaluation and future development appropriate?	4.86	0.38	Most
4. Digital Competency Development			
1. To what extent is the information and data literacy (Information & Data Literacy) appropriate?	5.00	0.00	Most
2. To what extent is the communication and collaboration with AI (Communication & Collaboration with AI) appropriate?	5.00	0.00	Most
3. To what extent is the creative and safe digital content creation and ethics (Digital Content Creation & Ethics) appropriate?	4.86	0.38	Most
Overall	4.88	0.33	Most

The expert evaluation of the TPL-DC Model indicates consistently high suitability across all assessed components, with an overall mean score of 4.88. Experts affirmed the model's conceptual soundness, noting strong coherence among its components and high practical applicability. The structural appropriateness and AI integration within teacher training environments received perfect or near-perfect ratings, suggesting that the model aligns well with current advancements in AI-enhanced instructional design. In the domain of training and personalized learning, experts endorsed key elements such as learner analysis, personalized goal-setting, adaptive content design, and technology-enhanced customization. These findings confirm that the model effectively embeds personalized learning principles supported by AI-driven adaptivity. Digital competency development covering information literacy, AI collaboration, and ethical content creation was also rated highly, reflecting the model's alignment with contemporary digital competency frameworks. Overall, the evaluation demonstrates that the TPL-DC Model is theoretically robust, pedagogically relevant, and practically feasible for AI-enhanced teacher training.

5. Discussion

The results of this study indicate that the systematic integration of generative AI within a personalized training framework can significantly enhance the development of teachers' digital competencies. The TPL-DC Model, constructed through the synthesis of structured training processes, personalized learning principles, and AI-enhanced instructional mechanisms, demonstrates strong conceptual coherence and practical feasibility. This discussion elaborates on the study's theoretical contributions, practical implications, and its alignment with prior research.

5.1 Theoretical Contributions

This study advances current knowledge by offering a unified conceptual framework that merges three domains historically treated as separate: training learning systems, personalized learning, and AI-supported instructional design. The TPL-DC Model conceptualizes these domains as mutually reinforcing, positioning training not as a linear sequence but as a dynamic, adaptive cycle. A key contribution is the articulation of a seven-stage Training Personalized Learning Process that integrates structured instructional components such as needs analysis, content development, and evaluation with personalization mechanisms including learner profiling, adaptive pathway design, and continuous data-driven refinement. Moreover, the explicit embedding of generative AI functions within each stage expands theoretical understanding of AI's role from supplementary support to foundational instructional infrastructure. The model also advances digital competency theory by linking training activities to five core domains, demonstrating how competency-based expectations can be operationalized within AI-enhanced learning systems.

5.2 Practical Implications

The findings offer several implications for teacher training practice. First, the model enables institutions to transition

toward adaptive, data-driven professional development. AI-powered learner analysis and goal-setting mechanisms allow trainers to diagnose competency gaps with greater precision and construct personalized pathways aligned with institutional standards. Second, AI-enhanced content generation and tool selection reduce the workload associated with developing training materials, enabling trainers to focus on pedagogical decision-making. Third, integrating continuous monitoring and real-time adaptation provides learners with individualized feedback and support, which is crucial for sustained digital competency development. Finally, the model's scalability enables implementation across diverse educational contexts, supporting both centralized institutional training and individualized professional growth.

5.3 Comparison with Prior Research

The study's findings align with and extend existing literature. Previous work (Zawacki-Richter et al., 2019; Chen et al., 2022) highlights AI's potential to optimize learning processes, yet these studies typically examine isolated AI applications rather than full-cycle integration. The current model builds on this evidence by embedding AI mechanisms throughout all training stages. The emphasis on personalization corresponds with the works of Sharples (2023), Ng et al. (2023), and Yu and Guo (2023), who underscore the importance of adaptive learning profiles and feedback loops. However, this study extends their contributions by demonstrating how personalization can be systematically incorporated within institutional training structures. Moreover, the competency-focused design aligns with contemporary research on digital skills development (Mejías-Acosta et al., 2024), providing a structured pathway to align training with evolving expectations for AI literacy and ethical technology use.

5.4 Synthesis

Overall, the TPL-DC Model provides a theoretically grounded and practically viable blueprint for future-ready teacher training. By unifying structured training design, personalized learning theory, and generative AI capability, the model creates an adaptive ecosystem capable of cultivating the digital competencies required in AI-driven educational environments.

6. Conclusion

This study developed and validated the TPL-DC Model, a comprehensive framework that integrates generative AI, personalized learning principles, and systematic training processes to support teacher digital competency development. The model addresses a critical gap in existing professional development systems by merging structured instructional design with adaptive, data-driven personalization. Through theoretical synthesis, model construction, and expert validation, the study demonstrates that generative AI can serve as both an instructional catalyst and an analytic infrastructure for optimizing teacher learning experiences. The results confirm that the TPL-DC Model provides a coherent and practical structure comprising seven interconnected stages, each enhanced by AI-driven tools and processes. These stages, spanning learner analysis, pathway design, individualized content creation, adaptive implementation, and continuous evaluation, collectively form a dynamic ecosystem that supports personalized professional growth. Expert evaluation results, with an overall mean of 4.88, affirm the model's conceptual soundness, structural integrity, and applicability within real-world educational settings.

The model offers three significant contributions. First, it advances theory by synthesizing training design and personalized learning into an integrated AI-enhanced framework. Second, it provides a practical blueprint for institutions seeking to implement scalable, adaptive teacher training aligned with digital competency standards. Third, it demonstrates the potential of generative AI to enhance instructional design capacity, streamline personalization, and foster sustainable professional learning ecosystems. Future research should explore the model's implementation in diverse educational contexts, examine learner outcomes through longitudinal studies, and integrate additional AI capabilities such as multimodal analytics and autonomous tutoring systems. Overall, the TPL-DC Model represents a significant step toward future-ready teacher training environments, offering a robust foundation for cultivating the digital competencies required in an AI-driven educational landscape.

7. Limitations and Recommendations for Future Research

Although the TPL-DC Model demonstrates strong conceptual coherence and expert-validated suitability, several limitations should be acknowledged. First, the model was developed through theoretical synthesis and expert review without empirical implementation. Its practical effectiveness, scalability, and impact on digital competency development, therefore, require verification in real training environments. Second, the expert validation involved a

relatively small group of specialists, which may limit the representativeness of perspectives across diverse educational contexts and technological readiness levels. Broader or Delphi-based validation processes could strengthen future refinement. Third, the model assumes adequate access to generative AI tools and digital infrastructure, which may vary significantly across institutions. Constraints related to resources, AI policies, and digital readiness may affect adoption and require contextual adaptation. Finally, digital competency domains evolve rapidly; emerging areas such as multimodal AI literacy and responsible automation warrant integration in future iterations. Future research should implement the model through pilot studies, quasi-experiments, or longitudinal designs, and compare outcomes across varied contexts to enhance robustness and ensure long-term applicability.

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Authors contributions

Duangruethai Seewan contributed to the conceptual development of the training framework and participated in literature synthesis and model construction.

Rungfa Pasmala assisted in the theoretical integration of personalized learning and generative AI components within the model.

Tarattakan Pachumwon contributed to the design of the digital competency framework and assisted in data organization and analysis.

Bhibul Hongthong supervised the research process, coordinated expert validation, and critically revised the manuscript.

Thada Jantakoon provided overall research direction, contributed to conceptual design, and performed final manuscript revision and approval.

All authors read and approved the final manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Not applicable.

Ethics approval

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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