

Research on the Path and Training System for Enhancing AI Teaching Application Capability for Vocational Education Teachers

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ABSTRACT This paper addresses three typical problems encountered by vocational education teachers in AI-assisted teaching: unclear conceptual understanding, weak practical operation ability, and difficulty in innovative application. A three-in-one improvement system of “competency framework-training content-implementation path” is constructed. First, based on literature analysis and the Delphi method, a four-dimensional competency framework is developed, covering awareness and cognition, tool operation, instructional design, and ethical evaluation. Second, a modular training content system featuring tiered application and integration of theory and practice is designed according to this framework. Third, a cyclical empowerment path of “research-training-application-evaluation” is constructed. The system is validated through quasi-experimental research and longitudinal tracking. Results show that the training system significantly improves teachers’ AI teaching application capability, with the mean scale score increasing from 2.79 to 3.78, representing a relative increase of 35.5% and Cohen’s d of 1.78. The constructed scale shows good reliability and validity, with total $\alpha = 0.934$. Longitudinal tracking also reveals attenuation in tool-use frequency and innovative applications, indicating the need for sustained institutional support.

INDEX TERMS vocational education, artificial intelligence, teacher training, teaching application capability, instructional design

I. INTRODUCTION

CURRENTLY, the new generation of information technology represented by artificial intelligence is accelerating the profound transformation of vocational education teaching models and talent training systems to meet the high-precision technical demands of intelligent weaving machinery and automated production. This evolution ensures that the cultivation of technical expertise remains synchronized with the digital shift toward smart manufacturing and complex mechanical control [1]. However, as vocational education teachers confront this transformation, they generally face the significant challenge of insufficient AI teaching application ability, specifically manifested as “vague conceptual understanding” of the educational value of AI, “weak practical skills” in the use of tools, and “difficulty in innovative integration” in the deep integration of AI with professional teaching. This ability gap not only restricts the release of the potential of technology-enabled teaching, but also becomes a key bottleneck for the high-quality development of vocational education [2]. Therefore, systematically exploring the scientific connotation of vocational teachers’ AI teaching application ability, constructing

an effective improvement path and training system has urgent practical significance and important theoretical value [3,4].

Existing research mainly focuses on the general ability framework of teachers’ digital literacy or information technology, or conducts case studies on the application of a specific AI tool. Ng et al. argue that teachers’ AI digital competencies are essential for effectively integrating artificial intelligence into education and for cultivating students’ twenty-first-century skills in the post-pandemic digital learning environment [5]. Qureshi argues that artificial intelligence is reshaping teacher roles by promoting a collaborative human–AI pedagogy in which teachers act as facilitators who integrate AI tools to support personalized and interactive learning [6]. Based on their research on existing AI education resources and core AI content in the K-12 stage, Kim et al. used the TPACK framework to analyze relevant courses and resources, and then proposed the teacher capabilities required for K-12 artificial intelligence education [7]. Wannapiroon et al. examined the digital competences required for vocational instructors to effectively deliver synchronous online learning, highlighting the critical

role of technological pedagogical knowledge in the “next normal” educational landscape [8]. Amjad and Joshi show that artificial intelligence is increasingly integrated into material development and machine manufacturing, playing an important role in advancing intelligent and automated production systems [9]. However, these studies failed to closely integrate with the special context of “theory-practice integration” and “job orientation” in vocational education, and failed to construct a development plan for AI teaching application capabilities that is both systematic and operable, and has been empirically tested. To address the aforementioned shortcomings, this study employs a closed-loop research path of “theoretical construction - system design - empirical verification.” First, by integrating competency framework theory with vocational education pedagogy, a specific competency model is constructed. Then, based on the laws of adult learning and teacher professional development, progressive training content and implementation paths are designed.

Finally, a series of empirical studies scientifically evaluate the effectiveness of the training system. This methodology aims to overcome the limitations of previous research that emphasized theory over practice or design over verification, providing a complete and reliable solution to the core issues. Results show that the constructed system significantly and continuously improves teachers’ AI teaching application capabilities within the context of intelligent weaving and automated machinery control, providing a systematic theoretical basis and practical paradigm for the digital transformation of vocational educators in these high-precision industrial sectors.

II. CONSTRUCTION AND VERIFICATION OF THE COMPETENCY FRAMEWORK

As for the construction of framework, its path of “theoretical induction - practical adaptation - expert consensus” is “top-down”. Firstly, the research system introduced related theories of teacher professional development, technology acceptance and integration (TPACK etc.) and application in artificial intelligence education, and initially speculated that vocational teachers should transit over the whole competency spectrum from cognitive understanding to innovative practice in this field. Then, the research group fielded in many vocational colleges. Through classroom observation and interviews with teachers, we found that frontline teachers had a strong desire to use AI tools, but faced many challenges in adapting general technology to highly contextualized, skill-based professional course teaching. Comparing with theory and practice, an applicable competency framework cannot be simply technical operation, but should enter into the teaching logic of vocational education [10].

In order to make the framework both scientific and practical, we used the Delphi method to conduct two rounds of expert opinion consultation. A group of twelve experts, including vocational education research, educational technology, industry technology experts and national teaching masters,

was invited. Experts fully affirmed the four core dimensions of the preliminary framework—“AI teaching awareness and cognition,” “tool operation and data processing,” “AI-integrated instructional design,” and “AI application ethics and evaluation”—and deepened their connotations. The consensus was that the “awareness and cognition” dimension needs to strengthen the understanding of the connection between AI-enabled cultivation of “craftsmanship spirit” and industrial transformation; the “instructional design” dimension must emphasize the ability to create human-machine collaborative learning scenarios oriented towards the work process; and the “ethical evaluation” dimension is particularly important in vocational education, requiring special attention to student data security, the fairness of algorithmic decision-making, and the objective evaluation of the effectiveness of technology applications.

III. LAYERED DESIGN OF TRAINING CONTENT SYSTEM

After establishing the four-dimensional competency framework of “awareness and cognition, tool operation, instructional design, and ethical assessment”, this study follows the principles of “learner-centered” and “differentiated development”. The core design logic of this system is “layered advancement”. We divide the training content into three interconnected and spiraling levels: basic popularization level, skills deepening level, and innovation integration level. The basic popularization level is open to all participating teachers, with the key objective of fostering foundational awareness and addressing initial cognitive barriers to AI adoption. Its content closely follows the dimensions of “awareness and cognition” and “basic tool operation”, and through a large number of vivid cases from vocational education (such as AI-assisted virtual simulation training and intelligent diagnosis of learning difficulties), it intuitively reveals the revolutionary impact of AI on teaching models and talent cultivation, and resolves teachers’ unfamiliarity and fear of difficulty. At the same time, it guides teachers to personally experience 1-2 user-friendly AI generation tools (such as those used to create lesson plans or exercises), facilitating the transition from passive awareness to active application and establishing a preliminary sense of technical efficacy. The Skills Deepening Layer is geared towards teachers who have mastered basic operations and are willing to apply them in greater depth, focusing on “strong design and analytical skills.” This layer shifts its focus to “integrated AI-based instructional design” and “data processing” capabilities. We have designed a series of micro-tasks based on real professional courses (such as CNC programming, marketing, and nursing procedures). For example, mechanical engineering teachers are required to use AI tools to generate an interactive script for troubleshooting a typical part machining fault, or business teachers are required to design a telephone marketing training scenario driven by AI virtual customer service. In this process, the training not only guides teachers on how to use more complex tools (such as data analysis platforms and intelligent dialogue

engines), but also emphasizes guiding teachers to conduct “instructional design review”: Why was AI introduced here? Which traditional teaching session was replaced? How to evaluate its effectiveness? Through this close integration of “technical practice” and “pedagogical reflection,” teachers are encouraged to transition from “tool users” to “instructional designers.”

The Innovation Integration Layer is intended for a limited number of outstanding teachers or professional leaders with relatively good integration abilities who need to make a leap and breakthrough. The goal is to “promote innovation and become a model”. Generally speaking, the content is highly open and highly integrated with “innovation integration” and “ethical assessment”. Usually interdisciplinary “innovation work shops” or “specialized projects”, requiring teachers to systematically integrate multiple AI technologies into a comprehensive teaching project (creating a high-quality online course, a complete practical training project, etc.); rigorously assess and formulate plans for the effectiveness and possible application risks of the target technology (such as students’ data profiling boundaries, generative evaluation fairness, etc.) Applications) Innovation practice cases with school-based or professional characteristics are produced as outputs. These cases are fed back into the high-quality materials of the first two levels of training, forming a good circle of content ecology.

In order to effectively implement training at this level, it is consistent with the principles of “integration of theory and practice” and “scenario-based learning” throughout the content system. All explanations of theory are embedded in specific tasks, and all skills training is aimed at a real or simulated teaching problem. We have constructed an “AI + Professional Teaching” scenario case library for major professional categories, allowing teachers to learn their own knowledge in contexts closely related to their own work, ensuring both the systematicness and scientific nature of training, and providing enough flexibility and relevance. Teachers with different starting points can achieve effective improvement in their own “zone of proximal development”, providing content assurance for the subsequent “cyclical empowerment” implementation path.

IV. DEVELOPMENT OF AN INTEGRATED IMPLEMENTATION PATH FOR “RESEARCH, TRAINING, APPLICATION, AND ASSESSMENT”

This study breaks away from the linear, one-way instruction model and proposes and developed an integrated, cyclical empowerment implementation path of “research-training-application-assessment”. The implementation path starts with “research”. Through precise diagnosis, research analyzes needs and problems of teachers in a context-specific way. Before the official training starts, we firstly use the previously developed “AI Teaching Application Ability Scale” to assess teachers’ participation and, combined with the research on professional characteristics of courses of teachers and existing IT context, derive a “capability-

context” diagnostic map for each teacher. This process anchors ubiquitous training content to teachers’ initial context and further to their real teaching problems and positions the training targets with a clear personal relevance and problem-oriented motivation from the very beginning. This approach fosters intrinsic motivation, shifting teachers’ perception from passive compliance to active engagement. The next step is “training”. It is an intensive learning process highly interactive and embedded with practice. We use a hybrid model of “core workshops + project-based learning”. Through concise and efficient explanations and intensive exercises, research helps to quickly overcome cognitive barriers and technical skills. Then teachers work in small groups to learn based on a real-world “micro-project” derived from their own teaching (develop an AI-assisted fault diagnosis teaching module or design an intelligent question-and-answer system for after-class tutoring). In this process, the trainer acts as a coach and collaborator to provide immediate scaffolding support. Throughout the process we use an online collaborative platform to facilitate teachers’ resource sharing, collaborative creation and process recording, and initially build an online practice community.

The end of training marks the beginning of “application”. It is an important stage for skills transfer. We clarify “practice transformation” tasks and support mechanisms. In training, each teacher is required to implement at least one designed AI-integrated lesson in their classes within one month after the end of training and submit a complete teaching implementation plan, classroom recordings and student feedback. In the meantime, we regularly organize online “practice clinics” where training mentors and peers give targeted guidance. At the same time, we encourage teachers to keep “practice logs” to record the confusion, surprise and transformation they would encounter in application, and make their individual practical experience explicit. Finally, the “evaluation” stage not only evaluates teachers’ learning outcomes but also optimizes the whole learning path.

We build a multi-faceted evaluation system: this includes both rubric-based expert evaluation on teachers’ final submitted lessons and qualitative analysis of their practice logs to understand the practice transformation process and pain points.

V. EMPIRICAL EVIDENCE AND ITERATION OF THE TRAINING PROGRAM

For the pilot implementation, we first selected the representativeness and controllability of learning environment based on two secondary vocational schools with different geographical characteristics, professional settings and development stages as our cooperation objects. We also selected some teachers from different departments with certain interests but different base as the first pilot class. The implementation process strictly followed the integrated “research, training, application and assessment” plan we developed before. However, in the process of implementation, the role of research team changed from simple designers

into participatory observers and recorders. We not only collected “process evidence” on whether the training was carried out as planned, but also collected more “process evidence” through the following ways: participation observation records during training, dialogue and questions in workshop, dynamic group cooperation in project-based learning, teachers’ interaction traces in online platform, and most importantly—lesson plans, reflection logs and real problems in subsequent teaching practice.

Collection and analysis of data for in-depth “reflection”. The purpose of data collection and analysis was not simply to assess the success or failure of the program, but to understand its internal operation mechanism and external constraint conditions. For example, in the explanation of general-purpose tools in “Tool Operation” module, it was found that teachers from different majors (engineering vs. humanistic) could not get effective explanation, and they were more interested in explaining the application plugins that could directly connect to the professional software they used or the professional data they had. In “Practice Transformation” stage, some teachers could finish the design of lesson examples, but their designs were very rigid, and AI technology could not be well integrated with teaching objectives and professional skills training. This indicates the need of more training in “Instructional Design” dimension. In addition, due to the structural constraints caused by teaching tasks and school support, another external variable also appears, which has become an important variable affecting skills transfer.

Based on the “evidence” and “reflection” collected in an orderly way in each action cycle, we carried out targeted “iterative” optimization on the training program. This iteration was also multi-layered: at the content level, we enriched the “AI+%Professional Teaching” case library and developed more targeted tool guidebooks and design templates for different professional categories, making the content of training more practical; at the path level, we strengthened the transition support between “training” and “application”, designed a debriefing link in “Instructional Design Workshop”, and established cross-school “Subject-Based Teaching and Research Partner” cross-school mechanism to provide more continuous peer support for teachers; at the support environment level, we communicated with the management of pilot schools to make successful lesson examples included in the scope of assessment incentive for teaching assessment, and tried to provide teachers with easy access to AI tool accounts, trying to eliminate some dead angles in terms of system and resources.

VI. EVALUATION OF SYSTEM IMPLEMENTATION EFFECTIVENESS

A. EXPERIMENTAL SETUP

To comprehensively and systematically evaluate the effectiveness and practical feasibility of the integrated training system (“competency framework-content system-implementation path”) developed in this study, a mixed

research method was adopted. An evaluation scheme including three successively layered and interactively strengthened experiments was designed and implemented. The overall experimental design followed the logic of “tool development → effectiveness verification → mechanism in-depth description” and was aimed at assessing the training system from the three dimensions of measurement reliability, intervention validity, and practical sustainability. Specifically, to quantify the improvement in AI teaching application ability, this study defines the relative improvement rate as the percentage change in the mean scale score relative to the pre-test baseline: $(\text{Post-test Mean} - \text{Pre-test Mean}) / \text{Pre-test Mean} \times 100\%$. While this metric provides an intuitive measure of growth, it is interpreted as the relative increase in the observed scale scores rather than a direct percentage increase in the underlying latent construct. All statistical significance is further verified through t-tests and effect size calculations (Cohen’s d).

B. DEVELOPMENT AND RELIABILITY/VALIDITY TESTING OF THE AI TEACHING APPLICATION ABILITY SCALE

This study surveyed 215 vocational education teachers. According to a theoretically constructed four-dimensional ability framework for AI teaching application, exploratory and confirmatory factor analyses were used to examine the construct validity of the scale, and reliability analysis was used to examine the internal consistency and test-retest reliability of the scale. All analyses were aimed at “Vocational Education Teachers’ AI Teaching Application Ability Scale” with psychometric properties. This study was approved by the Ethics Committee of XinXiang Vocational and Technical College, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

Figures 1 (a-c) respectively represent the model fit indices, reliability analysis results, and convergent validity analysis of the AI Teaching Application Ability Scale, comprehensively demonstrating the psychometric

characteristics of the scale. Confirmatory factor analysis showed that the four-factor model fit well ($\chi^2/df = 1.567$, RMSEA=0.052, CFI=0.943, TLI=0.936, SRMR=0.042). The overall Cronbach’s α coefficient of the scale reached 0.934, with α coefficients for each dimension ranging from 0.867 to 0.901. The four-week test-retest reliability was 0.892. These results indicate that the scale possesses good construct validity, internal consistency, and time stability, making it a reliable tool for diagnosing and assessing vocational teachers’ AI teaching application abilities.

C. QUASI-EXPERIMENTAL STUDY OF THE “TIERED-PRACTICE” TRAINING PATH

In this study, pre- and post-test quasi-experimental design with unequal control group was used. From two vocational schools in the same region, eighty professional course teachers were chosen and randomly assigned into experimental

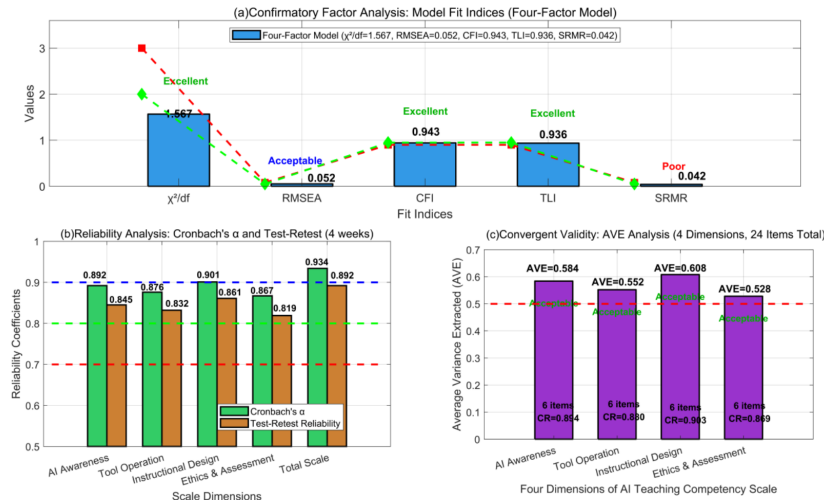


FIGURE 1. Development and Reliability/Validity Comparison of the AI Teaching Application Ability Scale

group ($n=42$) and control group ($n=38$). The experimental group participated in 12 weeks of training according to the “tiered-practice” concept, while the control group only participated in self-study of basic materials. AI Teaching Application Ability Scale was used to evaluate the teachers’ ability before and after. Then, the AI Teaching Project works of experimental group were collected and analyzed in order to confirm the effectiveness of the training path on ability improvement.

TABLE 1. Quasi-experimental comparison of the “tiered-practice” training path

Group	Sample Size	Pre-test Score (M $\pm$ SD)	Post-test Score (M $\pm$ SD)	Score Increase	Increase Rate
Experimental Group	42	2.79 $\pm$ 0.52	3.78 $\pm$ 0.45	0.99	0.355
Control Group	38	2.81 $\pm$ 0.48	2.92 $\pm$ 0.51	0.11	0.039

In Table 1, the post-test ability score of the experimental group ($M=3.78$) was significantly higher than that of the control group ($M=2.92$), $t(78)=8.47$, $p<0.001$, Cohen’s $d=1.78$. Based on the mean scale scores, the experimental group demonstrated a relative improvement of 35.5% compared to their pre-test baseline. In the project work quality assessment, the experimental group scored significantly better than the control group ($M=2.83$) in the AI-integrated instructional design dimension ($M=4.21$), $p<0.01$. The results show that the “tiered-practice” training path can effectively and significantly improve the AI teaching application capabilities of vocational education teachers.

D. LONGITUDINAL CASE TRACKING OF COMPETENCY TRANSFER AND TEACHING BEHAVIOR

The method of multi-case longitudinal tracking was used in this study. Six typical cases were chosen from experimental group which finished the training according to their subject background and training achievement. During the whole

semester after training, their application frequency of AI tool, selection and adaptation process of learning strategy were followed up and analyzed by monthly semi structured interviews, video collection of classroom teaching and text log collection.

TABLE 2. Longitudinal Case Comparison of Skills Transfer and Teaching Behavior

Tracking Phase	Average Frequency of AI Tool Use (times/week)	Proportion of Innovative Application in Classroom Teaching	Sustained Application (by end of semester)
Upon training completion	3.5	42%	—
Mid-semester	2.8	38%	5/6 (83.3%)
End of semester	2.1	31%	4/6 (66.7%)
Overall Mean / Proportion	2.8	37%	4/6 (66.7%)

In Table 2, teachers face a decreasing trend in the application of AI teaching skills in real classrooms: the average frequency of AI tool use at the end of the semester (2.1 times/week) decreased by 40% compared to the end of training (3.5 times/week), and the proportion of innovative applications decreased from 42% to 31%, respectively—should be interpreted as indicative trends within this specific cohort rather than as definitive evidence of universal attenuation patterns. Nevertheless, these observations suggest that even motivated early adopters face sustainability challenges, highlighting the need for further large-scale research to quantify the extent of capability retention and identify effective maintenance strategies. Future studies should expand the sample size and employ mixed methods to validate and extend these preliminary findings.

VII. CONCLUSION

This study developed a training system—comprising a competency framework, training content, and implementa-

tion path—tailored to the AI teaching needs of vocational educators in intelligent manufacturing contexts. Quasi-experimental results demonstrated immediate and significant gains: the experimental group showed a 35.5% improvement with a large effect size (Cohen's $d = 1.78$). The four-dimensional competency scale exhibited strong reliability and validity ($\alpha = 0.934$). However, longitudinal tracking revealed natural attenuation over time: average tool use frequency declined from 3.5 to 2.1 times/week (a 40% drop), and innovative applications fell from 42% to 31%. These findings indicate that while the system effectively initiates capability development, sustained integration requires ongoing institutional support. Limitations include the pilot-based sample; future research should validate generalizability and explore adaptive, data-driven approaches to foster long-term, self-sustaining teacher growth in AI-enhanced vocational education.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of XinXiang Vocational and Technical College, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

AUTHOR CONTRIBUTIONS

Lidan Zhai designed, collected and analyzed the data, and drafted the manuscript. Lidan Zhai conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Lidan Zhai participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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