

AI-DRIVEN PERSONALIZED LEARNING IN CHINESE VOCATIONAL EDUCATION: THE ROLE OF TEACHER DIGITAL COMPETENCE AND STUDENT ENGAGEMENT

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Abstract: As artificial intelligence (AI) becomes increasingly integrated into education, AI-driven personalized learning is emerging as a promising approach to improve instructional quality, particularly in vocational contexts. This study examines the relationships among AI-driven personalized learning, teacher digital competence, student engagement, and teaching effectiveness in Chinese vocational education. Using survey data from 511 vocational teachers, the results show that AI-driven personalized learning significantly enhances both teaching effectiveness and teacher digital competence. Furthermore, teacher digital competence exerts a significant positive influence on teaching effectiveness and serves as a partial mediator between AI-driven personalized learning and teaching outcomes. In addition, student engagement significantly moderates the relationship between AI-driven personalized learning and teaching effectiveness, such that the positive impact of personalized learning is stronger at higher levels of student engagement. These findings underscore the importance of strengthening digital competencies among vocational educators and fostering student engagement to maximize the impact of AI-supported instruction.

Keywords: AI-Driven Personalized Learning, Teacher Digital Competence, Teaching Effectiveness, Vocational Education

Introduction

The integration of Artificial Intelligence (AI) in education is rapidly reshaping teaching practices and learning experiences worldwide. In China, vocational education-an essential pathway for developing skilled labor and supporting economic growth-is undergoing a transformation driven by AI-powered personalized learning. As part of the national Smart+ Education initiative, tools such as

adaptive training platforms, automated assessments, and virtual simulations are being introduced into vocational classrooms. These innovations aim to tailor instruction, boost learning efficiency, and strengthen practical skill development (Annamalai et al., 2025). They challenge the traditional "one-size-fits-all" approach by adapting content and pacing to individual learner needs.

In this context, AI-driven systems support vocational learning by analyzing students' competencies and performance data, offering real-time feedback and customized guidance. This approach enhances skill mastery while fostering learner autonomy and engagement (Dai, 2023). Platforms like Squirrel AI and TAL Education Group have adapted machine learning models to vocational scenarios, providing hands-on, responsive learning experiences (Duan & Zhao, 2024).

Yet, the success of AI-driven personalized learning depends not only on the technology itself but also on two critical human factors: teachers and students. Teachers' digital competence—particularly their ability to integrate AI tools into instruction—serves as a key mediating variable affecting teaching effectiveness. Meanwhile, students' willingness to engage with AI platforms significantly shapes learning outcomes. Broader challenges such as infrastructure gaps, ethical concerns, and data privacy risks must also be addressed. Without attention to these issues, AI may inadvertently deepen existing educational inequalities across regions and institutions.

This study explores the impact of AI-driven personalized learning on teaching effectiveness in the context of Chinese vocational education, with a particular focus on the mediating role of teacher digital competence. It also examines whether student engagement moderates the relationship between AI-driven personalized learning and teaching effectiveness. The empirical findings aim to guide the development of inclusive and effective AI-integrated vocational education systems.

Research Objectives

1. To examine the direct effect of AI-driven personalized learning on teaching effectiveness in Chinese vocational education.
2. To examine the effect of AI-driven personalized learning on teacher digital competence.
3. To examine the influence of teacher digital competence on teaching effectiveness.
4. To analyze the mediating role of teacher digital competence in the relationship between AI-driven personalized learning and teaching effectiveness.
5. To investigate the moderating effect of student engagement on the relationship between AI-driven personalized learning and teaching effectiveness.

Literature Review

1. Theoretical Foundations of AI-Driven Personalized Learning

Self-Regulated Learning (SRL) theory emphasizes learners' ability to actively plan, monitor, and reflect on their own learning processes, which is particularly relevant in AI-driven personalized

learning environments. In vocational education, where students engage with adaptive learning paths, real-time feedback, and digital simulations, SRL becomes essential for navigating technology-enhanced tasks with autonomy. According to Zimmerman's model (2002), SRL involves three cyclical phases: forethought, performance, and self-reflection (Khamis, 2024). Research has shown that SRL improves outcomes in online and adaptive learning environments, while AI tools can further support SRL by providing timely feedback and visualized learning analytics (Molenaar et al., 2021). In this study, SRL theory offers a foundation for understanding how AI-driven systems and teacher guidance interact to foster student autonomy and enhance teaching effectiveness in vocational settings.

2. AI-Driven Personalized Learning in Chinese Vocational Education

China's vocational education system, driven by national initiatives such as Smart+ Education and the urgent demand for industry-ready talent, has increasingly embraced artificial intelligence (AI)-driven personalized learning. Unlike traditional academic education, vocational education emphasizes hands-on training and skill acquisition, making adaptive, learner-centered approaches particularly relevant (Li & Mohammad, 2025). AI-powered platforms provide individualized learning paths, automated assessments, and simulation-based instruction that closely align with vocational learning outcomes (Su et al., 2022).

Leading educational technology providers such as Tomorrow Advancing Life Education Group and New Oriental Education & Technology Group have integrated AI tools into vocational curricula to support personalized tutoring, real-time progress tracking, and targeted feedback (Duan & Zhao, 2024). These systems leverage big data and deep learning algorithms to identify students' learning gaps and dynamically adjust content, enabling learners to master specific competencies more efficiently. Despite these advancements, the effectiveness of AI in vocational education remains under discussion. Lin and Lan (2015) argue that while AI-enhanced instruction improves cognitive outcomes, it may neglect critical components of vocational learning such as creativity, collaboration, and practical engagement. Furthermore, an over-reliance on algorithmic recommendations may reduce students' autonomy and hinder the development of self-regulated learning strategies (Lin & Lan, 2015). These challenges highlight the need for deliberate, pedagogically informed integration of AI, led by digitally competent teachers.

Moreover, the growing use of AI in vocational education is underpinned by key national policies. The Smart+ Education Initiative, the Education Digitalization Strategy Action Plan (Ministry of Education of the People's Republic of China MOE, 2022), and the National Implementation Plan for Vocational Education Reform collectively emphasize the strategic integration of intelligent technologies into skill-based education. These documents promote AI as a means to personalize learning, improve teaching quality, and foster technical talent aligned with China's innovation-driven development goals. The Smart+ Education framework, in particular, advocates for real-time diagnostics, adaptive instruction, and intelligent learning environments in vocational settings. However, regional

disparities in infrastructure, uneven teacher preparedness, and varying levels of institutional support pose significant implementation challenges (MOE, 2022).

These contextual factors reinforce the importance of teacher digital competence—not only in operating AI tools but in adapting them to vocational contexts that demand practical, learner-centered instruction. As such, a deep understanding of China’s policy and institutional environment is crucial to evaluating the true effectiveness of AI-driven personalized learning in vocational education.

3. Teacher Digital Competence in AI-Enhanced Vocational Classrooms

In AI-enhanced vocational classrooms, teacher digital competence is essential for integrating intelligent technologies into skill-based instruction. Unlike general education, vocational education emphasizes practical training and competency development, requiring teachers to effectively utilize AI tools such as adaptive learning systems, intelligent assessments, and virtual simulations (Su et al., 2022; Duan & Zhao, 2024).

Digital competence in this context goes beyond basic technology use. It includes the ability to interpret AI-generated data, personalize instruction, manage simulation-based environments, and integrate AI feedback into formative assessment (Liu, 2024). Teachers must also support student engagement in AI-assisted tasks and ensure that technology enhances—not replaces—pedagogical effectiveness (Falloon, 2020).

In this study, teacher digital competence is viewed as a mediating variable that explains how AI-driven personalized learning leads to improved teaching effectiveness. When educators can meaningfully integrate AI into instruction, they transform these technologies into active enablers of student-centered, skill-oriented learning (Chiu et al., 2024; Falloon, 2020).

4. Teaching Effectiveness in AI-Enhanced Vocational Education

AI-driven personalized learning is increasingly improving teaching effectiveness in vocational education. Through adaptive skill training systems, AI analyzes students’ competencies and learning progress in real time to tailor instructional content and tasks, enabling targeted skill development and efficient mastery (Rane et al., 2023). In parallel, AI-supported performance assessment tools automate skill evaluation and provide instant feedback, allowing instructors to identify learning gaps and adjust teaching strategies accordingly (Sesay, 2024). Moreover, AI-powered digital simulations replicate real-world workplace scenarios, enhancing students’ hands-on abilities and professional readiness—both critical indicators of effective vocational instruction.

Beyond instructional precision, AI also contributes to greater efficiency and inclusiveness in teaching. By automating administrative tasks such as attendance, grading, and progress tracking, AI frees up teachers to focus on practical coaching and personalized support (Sesay, 2024). Technologies like real-time translation, speech-to-text, and flexible content presentation support students with language barriers or learning difficulties, improving equity and access in vocational classrooms (Abimbola, 2024). Importantly, AI can also analyze labor market trends, enabling educators to align

curricula with evolving industry needs. In sum, AI-driven personalized learning enhances teaching effectiveness through adaptive training, real-time assessment, and simulation-based instruction, making vocational education more targeted, inclusive, and industry-relevant.

Methodology

1. Research Design

This study adopts a quantitative, cross-sectional survey design to examine how AI-driven personalized learning influences teaching effectiveness in Chinese vocational education, with teacher digital competence as a mediating variable and student engagement as a moderating variable.

Data were collected through structured questionnaires and analyzed using descriptive statistics (means, standard deviations, frequencies), reliability testing (Cronbach's alpha), and confirmatory factor analysis (CFA) to assess the validity of the measurement model.

Structural equation modeling (SEM) was employed using software such as AMOS (or SmartPLS) to test both the mediation and moderation effects. Bootstrapping with 5,000 resamples was applied to estimate the significance of indirect effects, and interaction terms were used to assess moderation.

2. Population and Sample

This study surveyed 511 vocational education teachers in China with at least six months of experience using AI-driven personalized learning platforms. Stratified random sampling ensured balanced representation across regions, subject areas, and institutional AI readiness levels. All participants provided informed consent, and data were collected anonymously in accordance with ethical research standards.

3. Instrumentation

The primary data collection instrument is a structured questionnaire developed from validated existing scales and adapted to the Chinese vocational education context. All items were rated using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

AI-Driven Personalized Learning The scale was adapted from Mutambik (2024), measuring teachers' perceptions of AI in customizing learning paths, delivering real-time feedback, and supporting digital simulations in vocational training environments (Mutambik, 2024).

Teacher Digital Competence: Items were adapted from the scale developed by Ergül and Taşar (2023), focusing on teachers' ability to effectively integrate, manage, and apply AI tools in classroom instruction, while demonstrating ethical responsibility and professional awareness (Ergül & Taşar, 2023).

Teaching Effectiveness: Measurement items were adapted from Mubarak and Selimin (2023), focusing on perceived improvements in student competency development, teaching adaptability, and classroom innovation under AI-enhanced instruction (Mubarak & Selimin, 2023).

Cronbach’s alpha was calculated to evaluate internal consistency, with values above 0.70 considered acceptable. In addition to the main variables, demographic and contextual data such as teaching experience, subject area, institutional AI infrastructure, and prior student academic performance were collected as control variables.

Results

1. Descriptive Statistical Analysis

The sample consists of 511 vocational education teachers in China. Gender distribution is relatively balanced, with 52.3% male and 47.7% female respondents. Most participants are between 26 and 45 years old (65.8%), with the largest proportion aged 36–45 (37.4%). In terms of educational attainment, 56.2% hold a bachelor’s degree, 29.9% have a master’s degree, and 13.9% possess a doctoral degree or higher.

2. Structural Equation Modeling

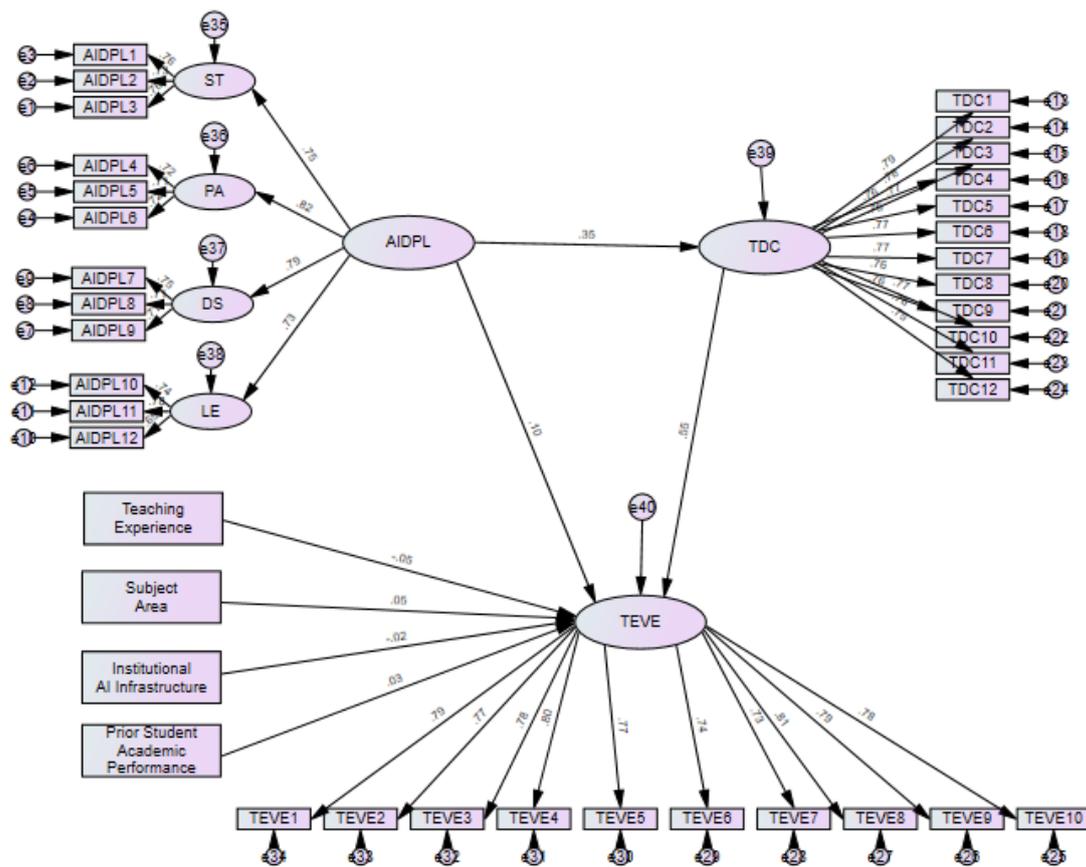


Figure 1: Structural Equation Modeling

Source: This study compiles

Table 1: Estimation of the baseline structural model

Item	Main Effect
Model fit	Model 1
χ^2/df	1.195
IFI	0.987
TLI	0.986
CFI	0.987
RMSEA	0.020
AIDPL→TEVE	0.348**(6.258)
AIDPL→TDC	0.097*(2.063)
TDC→TEVE	0.546**(10.904)

Mediation Test:

The results of the mediation effect test indicate that in the model where AI-driven personalized learning is the independent variable, teaching effectiveness in vocational education is the dependent variable, and teacher digital competence serves as the mediating variable, the indirect effect is 0.303. The 95% Bootstrap confidence interval ranges from [0.201, 0.450], which does not include zero. This suggests that the mediating effect of teacher digital competence is statistically significant in the relationship between AI-driven personalized learning and teaching effectiveness in vocational education, thus supporting the mediation hypothesis.

Table 2: Summary of Mediation Analysis

Path		Estimate	Lower	Upper	P
AI-Driven Personalized Learning → Teacher Digital Competence	Indirect Effect	0.303	0.201	0.450	0.000
Teacher Digital Competence → Teaching Effectiveness in Vocational Education	Direct Effect	0.155	0.018	0.340	0.018
	Total Effect	0.458	0.302	0.654	0.000

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Moderation Test:

Table 3: Results of Moderation Effect Analysis

	Model 1	Model 2	Model 3
Constant	3.429** (13.717)	3.598** (22.491)	3.484** (22.678)
Teaching Experience	-0.041 (-0.868)	-0.011 (-0.355)	-0.019 (-0.662)
Subject Area	0.045 (1.544)	0.012 (0.626)	0.023 (1.289)
Institutional AI Infrastructure	-0.008 (-0.202)	-0.001 (-0.041)	0.003 (0.136)
Prior Student Academic Performance	0.050 (1.298)	0.006 (0.225)	0.015 (0.620)
AI-Driven Personalized Learning	0.346** (5.632)	0.101* (2.509)	0.153** (3.906)
Student Engagement		0.777** (27.032)	0.780** (28.426)
AI-Driven Personalized Learning × Student Engagement			0.279** (7.055)
sample size	511	511	511
R ²	0.068	0.619	0.654
ΔR ²	0.068	0.552	0.034
F-value	7.323**	136.704**	135.625**

**Note: Dependent variable = Teaching Effectiveness in Vocational Education

$p < 0.05$, ** $p < 0.01$; t-values are reported in parentheses.

Model 1 includes only the control variables, yielding an R^2 of 0.068, indicating that basic factors such as teaching experience and subject area explain only 6.8% of the variance in teaching effectiveness. In Model 2, student engagement is added, and the R^2 increases substantially to 0.619, with a ΔR^2 of 0.552 and an F-value of 136.704, suggesting that student engagement has a strong explanatory power for teaching effectiveness. Model 3 further introduces the interaction term, resulting in an R^2 of 0.654 and a ΔR^2 of 0.034, with an F-value of 135.625**, indicating that the interaction between AI-driven personalized learning and student engagement significantly enhances the model's explanatory power. In Model 3, the regression coefficient for AI-driven personalized learning is 0.153** ($t = 3.906$), indicating a significant positive effect on teaching effectiveness. Student engagement also shows a strong positive impact, with a coefficient of 0.780** ($t = 28.426$). The interaction term yields a coefficient of 0.279** ($t = 7.055$), demonstrating that student engagement significantly moderates the relationship between AI-driven personalized learning and teaching effectiveness. In contrast, the regression coefficients for variables such as teaching experience and subject area are not significant ($p > 0.05$), indicating that their direct effects on teaching effectiveness are minimal.

Table 4: Simple Slope Analysis

Moderator Levels	Regression Coefficient	Standard Error	t	p	95% CI	
Mean	0.153	0.039	3.906	0.000	0.076	0.230
High Level (+1 SD)	0.436	0.061	7.134	0.000	0.317	0.556
Low Level (-1 SD)	-0.130	0.051	-2.567	0.011	-0.229	-0.031

When student engagement is at the mean level, each one-unit increase in AI-driven personalized learning leads to a 0.153-unit increase in teaching effectiveness. When student engagement is at a high level (+1 SD), this effect strengthens to 0.436 units and is highly significant ($t = 7.134, p < 0.001$). However, when student engagement is at a low level (-1 SD), AI-driven personalized learning has a negative effect on teaching effectiveness, with a regression coefficient of -0.130 ($t = -2.567, p = 0.011$).

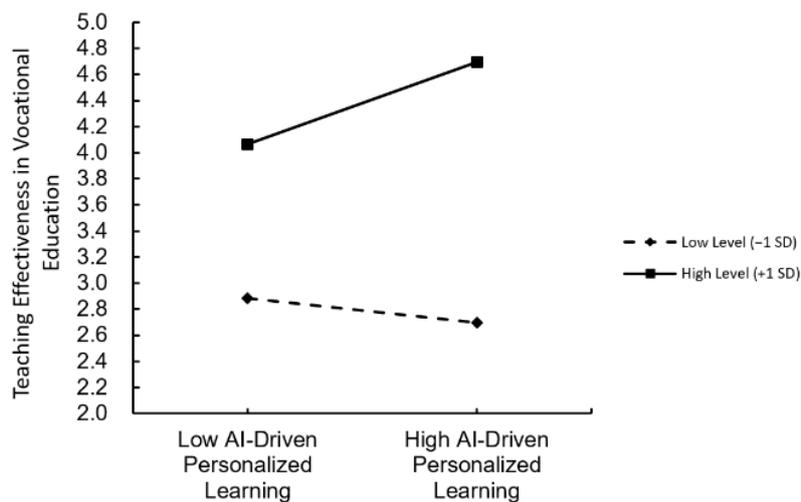


Figure 2: Moderation Effect

Source: This study compiles

Discussion

This study examined the impact of AI-driven personalized learning on teaching effectiveness in Chinese vocational education, emphasizing the mediating role of teacher digital competence. Findings indicate that AI tools—such as adaptive learning, real-time feedback, and digital simulations—significantly enhance instructional outcomes when effectively integrated by digitally competent teachers. This aligns with Li and Mohammad (2025), who noted the positive impact of AI on learning, particularly in well-resourced urban settings. The present study further clarifies that teacher digital competence is a key factor linking AI use to improved teaching performance. In line with Liu (2024), who highlighted the evolving role of teachers in AI-enhanced classrooms, the results underscore that

effective AI integration requires educators to adapt pedagogy, interpret learning data, and apply technology ethically. These insights suggest that policies promoting AI in vocational education should prioritize digital training for teachers, positioning them as facilitators of innovation. Future studies may explore long-term impacts across diverse institutional and regional contexts.

Conclusion

This study examined the impact of AI-driven personalized learning on teaching effectiveness in Chinese vocational education, highlighting both the mediating role of teacher digital competence and the moderating role of student engagement. The results demonstrate that AI-based instructional tools—such as adaptive skill training, real-time feedback, and digital simulations—significantly enhance teaching effectiveness, primarily through improved digital competence among teachers. Moreover, the positive impact of AI-driven personalized learning on teaching effectiveness is significantly strengthened when student engagement is high, whereas this effect diminishes or even reverses when engagement is low.

These findings suggest that to fully realize the benefits of AI in vocational education, institutions should focus not only on the adoption of intelligent technologies but also on strengthening teachers' digital capacity and actively fostering student engagement. Providing targeted training and support can enhance instructional adaptability and innovation, ultimately leading to better educational outcomes. This study offers practical insights for policymakers and educators aiming to build an effective, inclusive, and AI-integrated vocational education system.

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