Research on Path Design and Effect Verification of AI-Enabled Personalized Learning in Higher Vocational Education

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ABSTRACT Aiming at the prominent problems of unified teaching mode, inconsistent learning level of students, disconnection between teaching content and post competency requirements, and difficult personalized teaching implementation in higher vocational education, this paper constructs an artificial intelligence (AI) enabled personalized learning system framework for higher vocational colleges, and designs a four-stage closed-loop learning path of intelligent portrait diagnosis, adaptive path planning, personalized resource push, and dynamic effect iteration. Based on graph neural network (GNN) and large language model (LLM) technology, the system realizes multi-dimensional perception of students' learning characteristics, precise matching of vocational skill knowledge graphs, and dynamic optimization of learning paths. This paper takes the core courses of higher vocational Biopharmaceutical Major as the research object, carries out a 16-week quasi-experimental study, and verifies the application effect of the model through data statistics such as academic performance, skill assessment results, learning engagement and autonomous learning ability. The experimental results show that compared with the traditional teaching mode, the AI-enabled personalized learning path can significantly improve students' academic performance and vocational operational skills, effectively enhance learning initiative and independent planning ability, and solve the pain points of homogenized teaching in higher vocational education. The research can provide theoretical support and practical reference for the digital transformation of higher vocational teaching and the innovation of personalized talent training mode.

INDEX TERMS Artificial Intelligence; Higher Vocational Education; Personalized Learning; Path Design; Effect Verification; Knowledge Graph

I. INTRODUCTION

A. RESEARCH BACKGROUND

With the in-depth advancement of digital education reform and the iterative upgrading of vocational education reform, higher vocational education, as the main position of cultivating high-quality technical and skilled talents, puts forward higher requirements for personalized, refined and competency-oriented teaching training. Different from undergraduate academic education, higher vocational education focuses on post competency training, and students have significant differences in learning foundation, learning ability, skill operation level and career development orientation. However, the traditional higher vocational teaching mode adopts unified curriculum schedule, unified teaching content and unified assessment standards for a long time, which is difficult to adapt to the differentiated learning needs of students, resulting in the problems of "poor foundation students can't keep up, excellent students have no room for improvement", and seriously restricting the quality of talent training. In recent years, artificial intelligence technologies such as big data analysis, knowledge graph, large language model and adaptive learning algorithm have been widely applied in the field of education, providing technical support for breaking through the bottleneck of personalized teaching in higher vocational colleges. AI technology can realize full-cycle data collection and intelligent analysis of students' learning behaviors, accurately depict learners' individual characteristics, and dynamically generate exclusive learning paths matching their learning levels and post competency requirements, which effectively makes up for the deficiency of traditional teacher-led personalized teaching with limited energy. At present, domestic and foreign related researches mostly focus on the theoretical discussion of AI personalized teaching, and there are few systematic researches on the complete path design and quantitative effect verification combined with higher vocational professional teaching scenarios, lacking practical and operable implementation schemes and empirical data support. Therefore, it is urgent

to construct a systematic AI-enabled personalized learning path suitable for higher vocational education characteristics and verify its practical application effect.

B. RESEARCH SIGNIFICANCE

Theoretical Significance: This paper integrates artificial intelligence adaptive learning theory with vocational education competency-based training theory, constructs a closed-loop theoretical system of AI-enabled personalized learning for higher vocational education, enriches the research connotation of digital vocational education, and provides new theoretical ideas for the innovative development of personalized teaching in vocational colleges.

Practical Significance: This research designs a set of operable, replicable and popularized personalized learning implementation paths, which can effectively solve the pain points of homogenized teaching in higher vocational colleges. Through empirical verification, it confirms that the model can improve students' learning efficiency and vocational skill level, help teachers realize precise teaching, and provide practical reference for the digital transformation of higher vocational teaching and training reform.

C. RESEARCH CONTENTS AND INNOVATION POINTS

The main research contents of this paper include: first, analyzing the current problems of personalized learning in higher vocational education; second, constructing the overall framework of AI-enabled higher vocational personalized learning system; third, designing the four-stage personalized learning implementation path; fourth, carrying out quasi-experimental research and quantitative verification of application effects; fifth, summarizing the application advantages and existing deficiencies of the model, and putting forward optimization strategies.

The core innovation points are as follows:

(1) Different from general personalized learning models, this model is oriented to higher vocational post competency training, integrates professional knowledge graph and post skill standard database, and realizes the deep integration of personalized learning and vocational talent training goals;

(2) Constructs a dynamic iterative closed-loop path, which can adjust the learning strategy in real time according to students' learning feedback data, realizing true adaptive personalized teaching;

(3) Adopts quantitative experimental verification method, with multi-dimensional evaluation indicators, and the research results are more scientific and credible, meeting the practical application needs of higher vocational teaching.

II. CURRENT SITUATION AND PROBLEMS OF PERSONALIZED LEARNING IN HIGHER VOCATIONAL EDUCATION

A. OBVIOUS INDIVIDUAL DIFFERENCES OF STUDENTS

Higher vocational students come from different sources such as vocational high schools, technical schools and ordinary high schools, with great differences in basic knowledge, learning ability, learning habits and practical operation level. In the unified teaching mode, teachers can only carry out teaching according to the average learning level of students, which cannot take into account the differentiated needs of high, medium and low-level students, resulting in low overall teaching efficiency.

B. LIMITED PERSONALIZED TEACHING ABILITY OF TEACHERS

Higher vocational professional courses involve strong practicality and many skill points. A teacher needs to face dozens of students in one class, and it is difficult to accurately grasp the learning situation of each student in real time. Relying on manual observation and experience judgment to carry out personalized guidance has the problems of low efficiency, strong subjectivity and poor timeliness, which cannot meet the large-scale personalized teaching needs.

C. DISCONNECTION BETWEEN TEACHING CONTENT AND INDIVIDUAL NEEDS

Traditional higher vocational teaching resources are fixed and homogeneous, lacking hierarchical and differentiated resource design. The teaching content cannot be dynamically adjusted according to students' learning weaknesses and post development orientation, resulting in the disconnection between learning content and individual learning needs and industrial post requirements, which is not conducive to the cultivation of students' professional core competitiveness.

D. LACK OF DYNAMIC LEARNING EVALUATION MECHANISM

The traditional higher vocational teaching evaluation mainly relies on final examination and skill assessment, which belongs to summative evaluation. It lacks real-time monitoring and dynamic evaluation of the whole learning process, cannot timely discover students' learning problems and path deviations, and cannot form effective feedback optimization, resulting in poor personalized teaching effect.

III. DESIGN OF AI-ENABLED PERSONALIZED LEARNING PATH FOR HIGHER VOCATIONAL EDUCATION

A. OVERALL SYSTEM FRAMEWORK

Based on the teaching characteristics and existing problems of higher vocational education, combined with AI big data analysis and adaptive learning technology, this paper constructs a four-layer overall framework of AI-enabled higher vocational personalized learning system, including data collection layer, intelligent analysis layer, personalized service layer and effect evaluation iteration layer. The system takes learner portrait as the core, post competency standard as the orientation, and realizes the whole-process intelligent empowerment of personalized learning. The overall framework is shown in Figure 1.

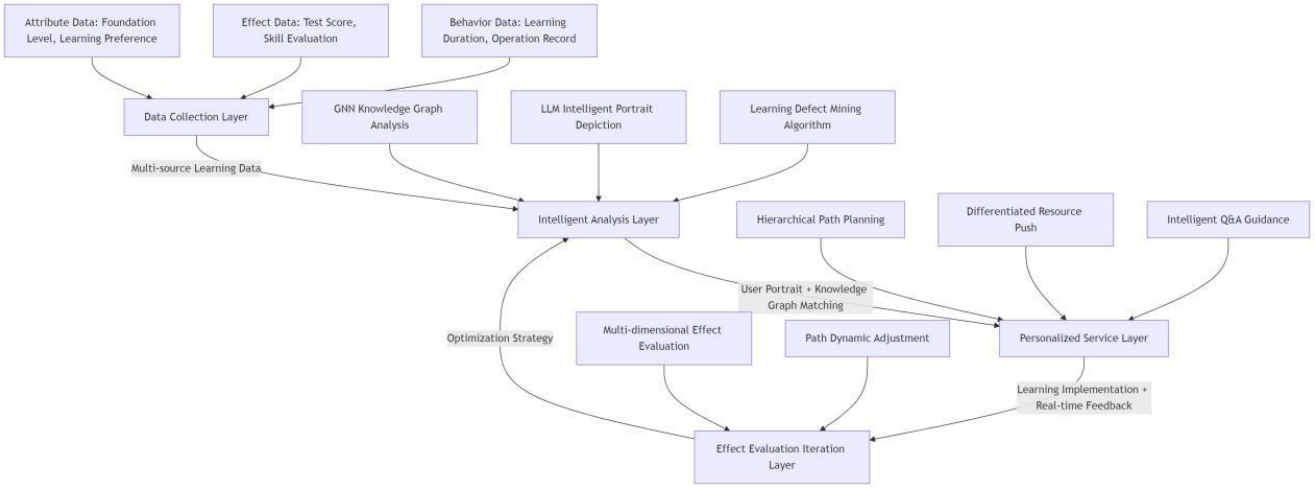

FIGURE 1. Overall Framework of AI-Enabled Personalized Learning System for Higher Vocational Education

The data collection layer is responsible for collecting multi-dimensional learning data of students' online and offline learning processes, including basic attribute data, learning behavior data, learning effect data and practical operation data. The intelligent analysis layer uses graph neural network to build professional knowledge graph, mines students' knowledge loopholes and skill weaknesses, and builds dynamic learner portraits. The personalized service layer realizes hierarchical learning path planning, accurate push of learning resources and real-time intelligent teaching guidance according to portrait characteristics. The effect evaluation iteration layer completes multi-dimensional evaluation of learning effects, feeds back evaluation data to the analysis layer, and realizes closed-loop dynamic optimization of learning paths.

B. FOUR-STAGE CLOSED-LOOP LEARNING PATH DESIGN

On the basis of the system framework, this paper designs a complete closed-loop personalized learning path including intelligent portrait diagnosis, adaptive path planning, personalized resource push and dynamic effect iteration, which covers the whole process of pre-class, in-class and after-class teaching.

1) Intelligent Portrait Diagnosis in Pre-class Stage

Before the start of the course, the system carries out comprehensive diagnosis of students' learning foundation, learning ability, learning preference and skill level through pre-class tests, questionnaire surveys and historical learning data. Combined with the higher vocational professional knowledge graph, it accurately identifies students' knowledge blind spots and ability deficiencies, and constructs multi-dimensional dynamic learner portraits including basic foundation dimension, learning ability dimension, skill operation dimension and learning preference dimension

2) Adaptive Path Planning in In-class Stage

Centering on the talent training objectives and post competency standards of higher vocational majors, the system matches the professional knowledge graph and post skill point database according to students' learner portraits, and generates exclusive adaptive learning paths for students of different levels. For basic weak students, it focuses on basic knowledge and basic skill training paths to make up for knowledge loopholes; for middle-level students, it focuses on knowledge consolidation and skill improvement paths to strengthen professional application ability; for excellent students, it focuses on comprehensive expansion and innovative practice paths to meet the needs of ability breakthrough and post high-level competency training. The learning path supports real-time adjustment according to classroom learning feedback.

3) Personalized Resource Push in After-class Stage

The system builds a hierarchical personalized learning resource database, including basic micro-lessons, skill operation videos, case analysis materials, post training tasks and vocational certificate assessment resources. According to students' learning path and real-time learning situation, it pushes differentiated resources accurately. For students with weak knowledge, it pushes basic consolidation resources; for students with skilled operation, it pushes comprehensive practical training and post expansion resources. At the same time, the AI intelligent assistant provides one-on-one Q&A guidance to solve students' personalized learning problems in real time.

4) Dynamic Effect Iteration in Whole Process

The system collects students' learning duration, exercise accuracy, practical operation completion degree, test scores and other full-process data in real time, carries out multi-dimensional evaluation of learning effects, analyzes path matching degree and learning problem points. According

to the evaluation results, it dynamically optimizes the subsequent learning path and resource push strategy, eliminates inappropriate learning links, and realizes the closed-loop iterative optimization of "diagnosis-planning-learning-evaluation-optimization".

C. KEY TECHNICAL SUPPORT

This research mainly relies on two core technologies to realize personalized learning path empowerment: First, the professional knowledge graph technology based on graph neural network, which constructs the mapping relationship of "professional knowledge points-skill operation points-post competency points", realizes the precise correlation of learning content and post requirements, and solves the problem of disjointed learning and employment; Second, the large language model adaptive recommendation algorithm, which analyzes students' learning behavior characteristics in real time, dynamically adjusts resource push and path planning strategies, and improves the accuracy and adaptability of personalized teaching.

IV. EXPERIMENTAL DESIGN AND EFFECT VERIFICATION

A. EXPERIMENTAL OBJECTS

This paper selects two parallel classes of Grade 2024 Biopharmaceutical Major in a higher vocational college as the research objects, with 45 students in each class, totaling 90 students. Among them, Class 1 is set as the experimental group, adopting the AI-enabled personalized learning mode designed in this paper; Class 2 is set as the control group, adopting the traditional unified classroom teaching mode. The two classes have the same teaching teachers, teaching syllabus, teaching hours and assessment standards, and there is no significant difference in pre-experiment academic performance and learning level ($p > 0.05$), which meets the experimental conditions.

B. EXPERIMENTAL CYCLE AND EVALUATION INDICATORS

The experimental cycle is 16 weeks, taking the core course as the teaching carrier. In order to comprehensively verify the application effect of the personalized learning path, this research constructs a multi-dimensional evaluation index system, including three dimensions: academic performance, vocational skill level and learning comprehensive quality. Academic performance includes theoretical test scores and usual homework completion; vocational skill level includes practical operation assessment scores and post simulation training results; learning comprehensive quality includes learning engagement, autonomous learning ability and learning interest.

C. EXPERIMENTAL RESULTS AND DATA ANALYSIS

1) Comparison of Academic Performance

After the 16-week experiment, the final theoretical test and usual performance data of the two groups of students were statistically analyzed, and the specific results are shown in Table 1.

TABLE 1. Comparison of Academic Performance Between Two Groups of Students

Evaluation Index	Experimental Group (Mean±SD)	Control Group (Mean±SD)	t-value	p-value
Theoretical Test Score	86.35±5.26	78.62±7.13	9.256	< 0.001
Usual Performance Score	92.18±3.58	83.45±6.22	10.362	< 0.001

It can be seen from Table 1 that the theoretical test score and usual performance score of the experimental group are significantly higher than those of the control group, and the difference reaches an extremely significant level ($p < 0.001$). It shows that the AI-enabled personalized learning path can effectively improve students' theoretical knowledge mastery degree and daily learning completion quality, and significantly improve academic performance.

2) Comparison of Vocational Skill Level

Combined with professional post skill standards and course training requirements, the professional teachers scored the students' practical operation and post simulation training. The skill level comparison results are shown in Figure 2.

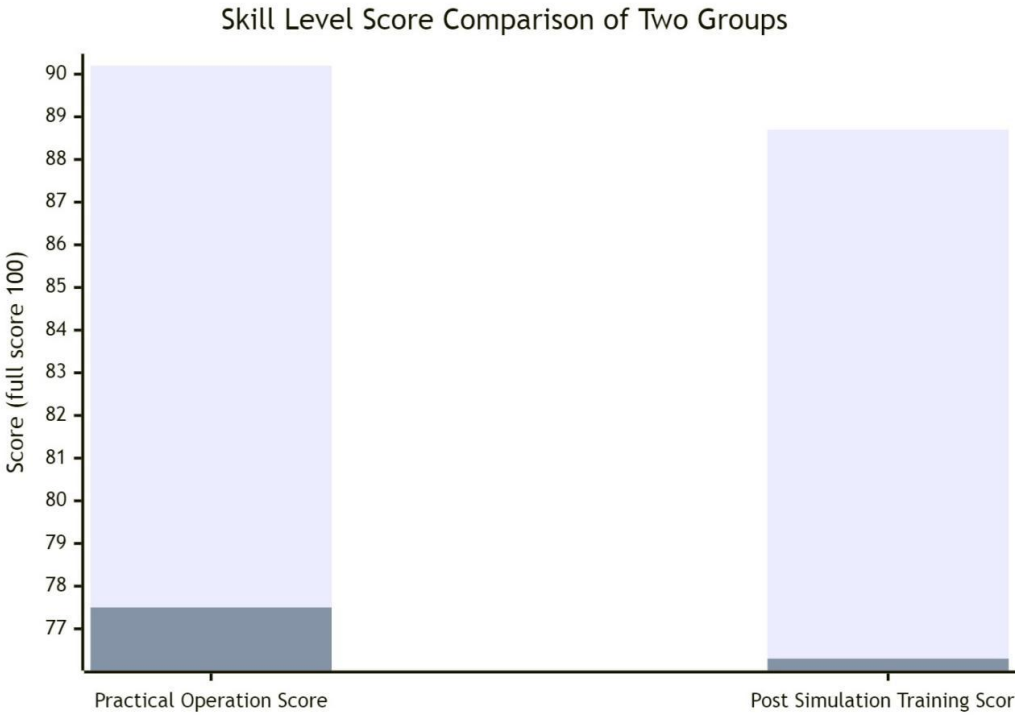

FIGURE 2. Comparison of Vocational Skill Level Scores Between Two Groups

The data shows that the average practical operation score of the experimental group is 90.2 points, and the post simulation training score is 88.7 points, which are 12.7 points and 12.4 points higher than those of the control group respectively. The personalized learning mode oriented by post competency can effectively target students' skill weaknesses for targeted training, significantly improve students' vocational operational ability and post adaptive capacity, and meet the training requirements of higher vocational technical talents.

3) Comparison of Learning Comprehensive Quality

This research adopts the mature higher vocational student autonomous learning ability scale and learning engagement scale to investigate the two groups of students. The survey results show that the learning engagement rate of the experimental group is 94.6%, which is significantly higher than 78.2% of the control group; the excellent rate of autonomous learning ability is 87.1%, which is much higher than 62.3% of the control group. In the personalized learning environment, students' learning goals are clearer, learning content is more in line with their own level, learning initiative and sense of acquisition are significantly improved, and the problem of passive learning in traditional teaching is effectively solved.

D. MODEL EFFECT VERIFICATION SUMMARY

The experimental results fully verify the effectiveness of the AI-enabled personalized learning path. First, the model realizes hierarchical and differentiated teaching, effectively solves the problem of uneven learning levels of higher vocational students, and improves the overall teaching quality; second, the model takes post competency as the orientation, realizes the deep integration of learning and post requirements, and improves students' vocational core competitiveness; third, the whole-process data monitoring and dynamic iteration mechanism realizes precise teaching guidance and significantly improves students' autonomous learning ability and learning engagement.

V. RESEARCH DEFICIENCIES AND OPTIMIZATION STRATEGIES

A. EXISTING RESEARCH DEFICIENCIES

First, the experimental sample scope is limited, and this experiment only takes the Biopharmaceutical Major as the research object, and the applicability of other majors such as liberal arts and service industry in higher vocational colleges needs to be further verified; second, the long-term tracking effect is insufficient, this experiment is a short-term 16-week quasi-experiment, and the long-term impact of the personalized learning mode on students' subsequent employment and career development needs long-term follow-up investigation; third, the system's independent learning optimization ability needs to be further improved, and individual extreme personalized learning scenarios still rely on manual intervention by teachers.

B. OPTIMIZATION STRATEGIES

First, expand the research sample scope, carry out cross-major and cross-school experimental verification, optimize the model framework according to the teaching characteristics of different majors, and improve the universality of the model; second, establish a long-term tracking evaluation mechanism, track and investigate the employment quality and career development of experimental students, and verify the long-term value of the personalized learning mode; third, further optimize the AI algorithm model, strengthen the system's independent reasoning and extreme scenario processing ability, reduce manual intervention, and realize fully intelligent adaptive personalized teaching; fourth, strengthen teachers' AI teaching literacy training, improve teachers' human-computer collaborative teaching ability, and build a new teaching mode of "AI empowerment + teacher guidance".

VI. CONCLUSION

Aiming at the homogenized teaching pain points in higher vocational education, this paper constructs an AI-enabled personalized learning system framework suitable for higher vocational teaching scenarios, designs a four-stage closed-loop learning path of intelligent portrait diagnosis, adaptive path planning, personalized resource push and dynamic effect iteration, and realizes precise, intelligent and differentiated teaching empowerment relying on knowledge graph and large language model technology. Through quasi-experimental research, it is verified that this learning path can significantly improve higher vocational students' theoretical academic performance, vocational skill level and comprehensive learning quality, effectively solve the problem of difficult personalized teaching in large-scale classes, and promote the high-quality development of higher vocational talent training.

In the future, on the basis of this research, we will further expand the research scope, optimize the algorithm model and system functions, improve the long-term evaluation mechanism, and build a more universal and intelligent personalized teaching system for higher vocational education, so as to provide stronger technical and theoretical support for the digital transformation and innovative development of vocational education.

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