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Research on the Smart Classroom Teaching Mode of PLC Courses in Secondary Vocational Schools Empowered by Artificial Intelligence

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Abstract

To address the problems of disjointed theory and practice, as well as inadequate adaptation to student learning contexts in the traditional teaching of the course PLC Control Technology and Application in secondary vocational schools, a smart classroom teaching model was constructed based on artificial intelligence (AI) technology. This paper analyzes the current teaching status of the course and the application value of AI, and conducts teaching design from four dimensions: teaching objectives, content reconstruction, process design, and evaluation system. A novel "AI-empowered 9+9 dual-process smart teaching model" is proposed. A one-semester teaching practice was carried out with 40 students majoring in mechatronics from the 2023 grade of Lanzhou Modern Vocational College as the research subjects, with a parallel class adopting traditional teaching methods as the control group. The practical data demonstrate remarkable teaching effectiveness: 83.78% of the students approved of the smart classroom teaching model, and the classroom interaction participation rate was 42% higher than that of the control group; 85% of the students were able to independently formulate preview plans, representing a 38% increase compared with the control group; the accuracy rate of practical training programming and the efficiency of equipment debugging were improved by 25% and 30% respectively. The final overall score of the experimental class was 10.2 points higher than that of the control group, with the theoretical score being 8.9 points higher; the passing rate reached 100%, and the excellent rate was 20% higher than that of the control group. The students' satisfaction with this teaching model stood at 92.3%. This study provides a replicable practical reference for the digital transformation of professional courses in secondary vocational schools, achieving the improvement of teaching quality and efficiency under the empowerment of technology.

Keywords

Artificial intelligence; Secondary vocational education; PLC control technology; Smart classroom; Teaching mode

1. Introduction

1.1. Research Background

With the rapid development of intelligent manufacturing, there is an urgent demand for PLC technical talents, requiring skills in programming, debugging, and innovation. The traditional teaching of the core vocational education course "PLC Control Technology and Application" suffers from issues such as outdated content, insufficient practical training, and incomplete evaluation. AI technologies like large models and virtual simulation can overcome these teaching limitations, enabling student performance analysis, resource delivery, and instructional optimization. Therefore, exploring an AI-powered PLC smart classroom teaching model holds significant importance.

1.2. Current research status at home and abroad

1.2.1. Current research status abroad

Foreign vocational education has been early in informatization, with mature integration of AI and professional courses. In Germany's dual education system, enterprises and institutions develop digital twin PLC virtual platforms to support blended virtual and real training. U.S. community colleges utilize AI teaching assistant systems to achieve personalized learning and real-time guidance. Theoretical research employs machine learning to analyze data, constructing intervention models such as adaptive learning systems to support personalized instructio.

1.2.2. Current research status in China

Domestic academic research on the technological integration, curriculum reconstruction, and industry-education collaboration in AI-enabled vocational education reform lays the foundation for the intelligent transformation of PLC courses in secondary vocational schools. Technological integration focuses on aligning technology with curricula, curriculum reconstruction emphasizes modular structure design, and industry-education collaboration advocates joint resource development among governments, enterprises, and schools. However, existing studies have limitations: systematic closed-loop design in technology application is lacking, empirical research on AI's end-to-end integration in PLC courses is absent, and evaluation systems have not broken free from traditional frameworks. Current research has yet to establish a comprehensive, dual-subject smart teaching model tailored to secondary vocational PLC courses, leaving room for exploration in building and empirically validating an AI-enabled "9+9" dual-process smart teaching model.

1.3. Research purpose and significance

1.3.1. Research Objective

Building an AI empowered intelligent teaching model for vocational PLC courses, with the goal of clarifying AI application scenarios and paths; Intelligent reconstruction of teaching content, process, and evaluation system; Validate the effectiveness of the model through experiments and provide replicable digital transformation solutions.

1.3.2. Significance of the study

Theoretical significance: Enrich the integration theory of AI and vocational education, construct a theoretical framework for intelligent teaching in vocational schools, and provide reference for curriculum reform.

Practical significance: To solve traditional teaching problems, optimize the teaching process, and enhance students' skills and job adaptability; Reduce the burden on teachers and improve teaching efficiency; Provide examples for the construction of smart campuses and teaching reforms.

2. Core concepts and theoretical foundations

2.1. Core concept

2.1.1. Artificial Intelligence

Refers to intelligent technologies and tools in the field of education, including core technologies such as AI big models, virtual simulation, machine learning, as well as application carriers such as intelligent teaching platforms and AI teaching assistants. The core functions include data collection and analysis, personalized push notifications, intelligent interactive feedback, virtual scene construction, etc., supporting smart classrooms.

2.1.2. Smart classroom

With the support of information technology, student-centered, intelligent technology and teaching concepts are integrated to achieve a new teaching form of precise teaching, personalized learning, and efficient interaction. The core features include precise perception of learning situation, intelligent adaptation of resources, dynamic optimization of teaching process, multi-dimensional evaluation, and improvement of teaching quality and learning efficienc.

2.2. Theoretical basis

2.2.1. Constructivist Learning Theory

This theory holds that knowledge is not simply one-way indoctrination by teachers, but rather active exploration and interactive communication by learners in specific contexts to construct meaning. This theory is one of the core foundations of the

teaching design in this study, supporting the "learning centered" dual process design of vocational PLC courses. The application of this theory in vocational PLC course teaching is manifested as: using AI to construct virtual industrial training scenarios, guiding students to collaborate in programming and debugging practices, and actively constructing core knowledge and skills such as PLC programming logic in solving practical industrial problems; At the same time, an interactive communication module is built through an intelligent platform to support students in sharing ideas, exploring difficult problems, and improving knowledge construction through thinking collisions.

2.2.2. Blended learning theory

Emphasizing the integration of online and offline learning advantages to optimize teaching effectiveness is highly compatible with the overall design of the "9+9 dual process" in this study. Its application in vocational PLC courses is as follows: before class, relying on online resources such as preview micro courses released by Chaoxing Learning Platform, using AI learning situation analysis to capture students' weak points, providing a basis for offline teaching; In class, offline physical training is the main focus, combined with virtual simulation software to carry out "virtual real integration" practical training to make up for the shortcomings of physical equipment; After class, personalized expansion resources are pushed by AI teaching assistants, and students' practice problems are solved through online Q&A, achieving seamless connection and complementary advantages between online and offline learning.

3. Analysis of the current teaching status of "PLC Control Technology and Application" course in secondary vocational education

3.1. Survey on the current status of course teaching

To comprehensively grasp the current situation of PLC course teaching in secondary vocational schools, a survey was conducted using questionnaire and interview methods. The research subjects were 12 PLC course teachers and 240 students majoring in mechanical and electrical engineering from 5 vocational schools in Gansu province. 232 valid questionnaires and 12 interview records were collected. The research content includes dimensions such as teaching objectives, teaching content, teaching methods, practical training conditions, and evaluation methods.

3.2. The main problems in teaching

3.2.1. Fuzzy positioning of teaching objectives, disconnected from job requirements

According to the survey, 68.3% of teachers believe that the current teaching

objectives focus more on imparting theoretical knowledge and lack attention to the practical skills and problem-solving abilities required for the position. The lack of hierarchical setting of course objectives and the failure to develop personalized goals based on students' cognitive differences and career development needs have resulted in a gap between teaching content and actual job requirements in enterprises, making it difficult for students to quickly adapt to their job positions after employment.

3.2.2. The teaching content is outdated and outdated, with a single presentation method

The current textbook content is not updated in a timely manner, and 72.5% of students have reported that the PLC models and programming cases in the textbook are disconnected from actual enterprise applications; The teaching content mainly focuses on theoretical knowledge, and practical cases lack systematicity and practicality. The teaching presentation method is still mainly based on "courseware explanation+blackboard demonstration", and abstract PLC working principles and programming logic are difficult to visually display through traditional methods, resulting in difficulties for students to understand and low learning interest.

3.2.3. The teaching method is rigid and lacks personalized guidance

65.8% of teachers still use the traditional teaching method of "theoretical explanation demonstration operation student imitation", which lacks interactivity and exploration; Due to the limitation of class size, teachers find it difficult to pay attention to the learning status of each student, and 83.2% of students believe that they have not received targeted learning guidance. The teaching process lacks a dynamic adjustment mechanism, which makes it difficult to optimize teaching strategies in a timely manner based on student learning feedback, resulting in poor teaching effectiveness.

3.3. Analysis of the causes of the problem

3.3.1. Lagging teaching philosophy

Some teachers still adhere to traditional teaching concepts, making knowledge transmission the core of teaching and neglecting the subject status and practical ability cultivation of students; Insufficient understanding of the teaching value of new technologies such as artificial intelligence, and a lack of awareness and ability to deeply integrate technology with teaching.

3.3.2. Insufficient resource construction

There is a scarcity of high-quality digital teaching resources, especially PLC virtual simulation resources and personalized learning resources that are suitable for the cognitive characteristics of vocational school students; Lack of systematic planning

for resource construction, existing resources are scattered and disorderly, making it difficult to form effective support; The low enthusiasm of enterprises to participate in resource construction has led to a disconnect between teaching resources and actual job positions.

3.3.3. Insufficient resource construction

PLC course teachers are mostly from traditional mechanical and electrical backgrounds, with 62.5% of teachers lacking the ability to apply artificial intelligence technology and practical experience in enterprises; The lack of systematic teacher training in schools makes it difficult for teachers to master the use of smart teaching tools and innovative teaching mode strategies, which hinders the promotion of curriculum and teaching reform.

4. Artificial intelligence empowers the design of smart classroom teaching for PLC courses

4.1. Teaching objective design

Based on the needs of professional positions and the cognitive characteristics of students, and leveraging the advantages of artificial intelligence technology, we have constructed a three-dimensional teaching objective system encompassing "knowledge, skills, and competencies"(As shown in Figure 1).

4.1.1. Knowledge objectives

Master the basic composition, working principle, and programming language of PLC, understand its control system design process and debugging methods, and be familiar with PLC application knowledge in typical industrial control scenarios.

4.1.2. Skill objectives

Possess the ability to operate PLC programming software, write, download, and debug programs, design and implement typical control systems, master fault diagnosis and troubleshooting methods, and utilize virtual simulation tools for practical training operations.

4.1.3. Literacy goals

Cultivate a rigorous and meticulous work attitude and a craftsman spirit of striving for excellence, enhance innovative thinking and problem-solving abilities, strengthen team collaboration and communication skills, and establish a lifelong learning mindset to adapt to the development needs of the intelligent manufacturing industry.

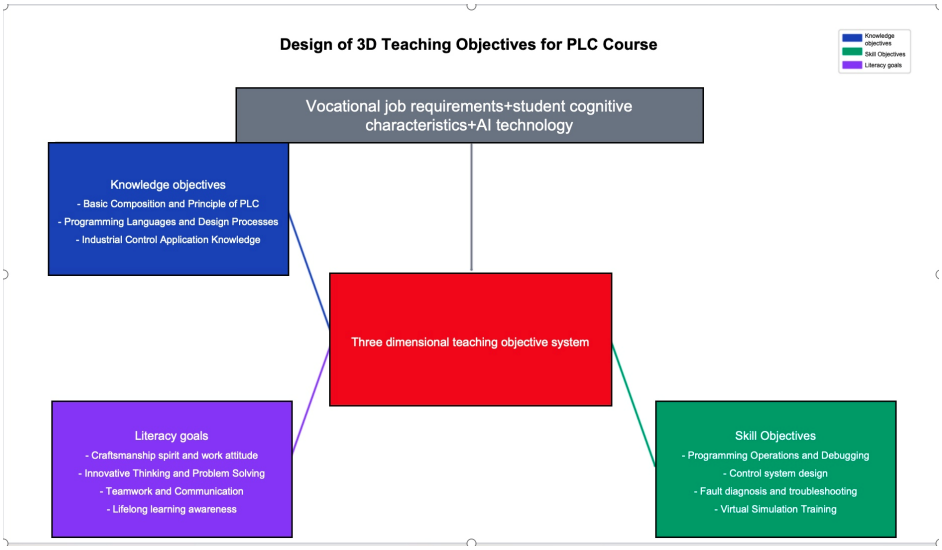


Figure 1. Smart Classroom Teaching Design for PLC Course

4.2. Reconstruction of teaching content

Guided by the actual needs of enterprise positions and combined with the characteristics of artificial intelligence technology, the teaching content of PLC courses is modularized and intelligently reconstructed, building a three-tier content system of "basic module - core module - expansion module"(As shown in Figure 2).

4.2.1. Basic Module

Including PLC basic knowledge, programming software operation, basic instruction application, etc. Through the AI intelligent learning guidance system, students are provided with theoretical explanations accompanied by illustrations, operation demonstration videos, and basic exercises; virtual simulation tools are utilized to construct simple control scenarios, enabling students to quickly grasp basic operational skills.

4.2.2. Core module

Covering the design and implementation of typical control systems PLC, including commonly used industrial scenarios such as motor control, pneumatic system control, and traffic signal control. Adopting a "case-driven + virtual training" approach, real industrial cases are pushed through the AI system, and students complete program design, debugging, and optimization in a virtual scenario; the system automatically records the operation process and generates a personalized ability improvement report.

4.2.3. Expansion module

Focusing on high-end PLC applications in the field of intelligent manufacturing, including the linkage control between PLC and touch screen, frequency converter,

and PLC applications in industrial IoT scenarios. Jointly develop virtual training projects with enterprises, where students complete comprehensive training tasks through group collaboration; AI systems provide project guidance and innovative ideas inspiration, cultivating students' comprehensive application abilities and innovative thinking.

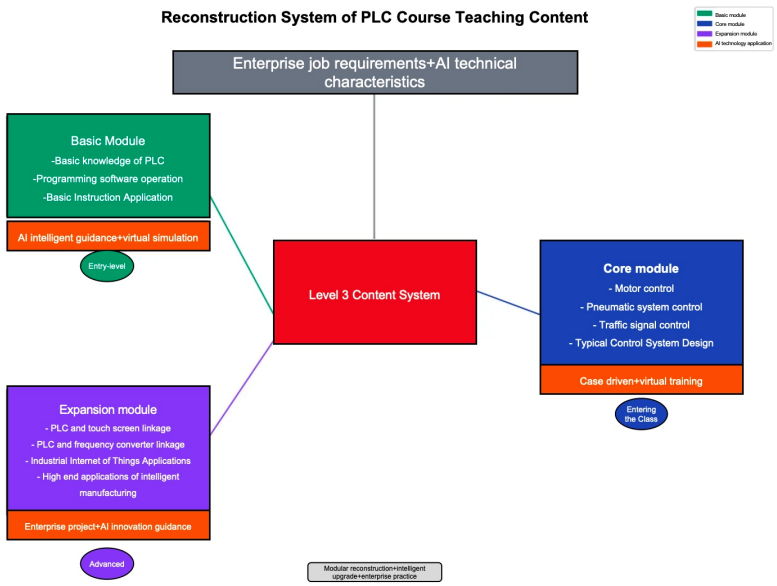


Figure 2. Reconstruction System of PLC Course Teaching Content

4.3. Teaching process design

Based on the theoretical analysis and AI adaptation scenario analysis mentioned earlier, and in conjunction with the teaching objectives of the PLC course in vocational schools, this study constructs an "AI-empowered 9+9 dual-process smart teaching model", clarifying the core tasks and implementation paths of both teachers and students before, during, and after class. It forms a logic of "goal orientation - process closed loop - evaluation feedback" and is implemented with the support of intelligent tools such as Chaoxing Learning Platform.

4.3.1. Pre-class session: Diagnosing learning situation and preparing for teaching

The pre-class learning diagnosis and teaching preparation involves 3 steps for teachers and 2 steps for students. Teachers sort out the PLC knowledge map, break down the objectives, release preview resource packages, generate reports through AI learning analysis, and then adjust the design and complete heterogeneous grouping based on the learning situation. Students complete resource learning and test feedback, obtain personalized supplementary resources, and lay the groundwork for classroom learning.

4.3.2. In-class activities: Precise teaching and interactive exploration

In-class precise teaching and interactive exploration involve 5 steps for teachers and 5 steps for students. Teachers issue task sheets, create industrial scenarios using VR, address learning weaknesses, assign group training, guide virtual programming and physical practice, monitor data, comment on errors, and organize summary assessments. Students participate in interactive exploration, complete virtual practice, peer-evaluate results, and take in-class assessments, identifying learning shortcomings.

4.3.3. After-class session: Expansion and Improvement, Evaluation and Feedback

The post-class expansion, improvement, and evaluation feedback process comprises one step for teachers and two steps for students. Teachers integrate the entire learning process data, utilize AI to generate comprehensive reports, push personalized expansion resources, and optimize subsequent teaching designs. Students complete post-class exercises, rely on AI teaching assistants for answers, review reports to summarize gains and losses, and submit reflection journals. This model relies on teacher-student collaboration and AI technology to form a teaching closed loop and address the pain points of traditional PLC teaching.

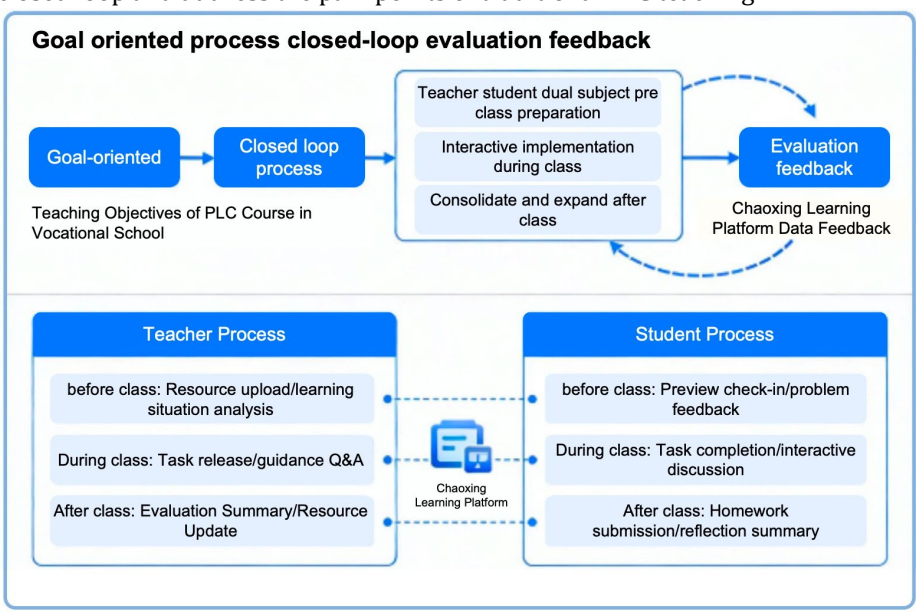


Figure 3. AI-enabled 9+9 dual-process intelligent teaching model

4.4. Design of teaching evaluation system

Adhering to the principles of "diverse evaluation, process orientation, and competency-based learning", we aim to construct a comprehensive teaching evaluation system supported by artificial intelligence.

The evaluation system comprises four dimensions, with specific evaluation indicators and weights set for each dimension. Details are provided in Table 1.

evaluation dimension	evaluation metric	weight	Evaluation method
Knowledge mastery	Theoretical knowledge test score	0.20	AI automatic evaluation + teacher review
	Knowledge application ability	0.10	Case analysis + AI scoring
Skill operation ability	Operational standardization of virtual training	0.15	Automatic evaluation of virtual simulation system
	Proficient in real equipment operation	0.15	Teacher evaluation + equipment data collection
	Fault diagnosis and troubleshooting capability	0.10	Practical training task assessment + AI scoring
Learning process performance	Quality of preview completion	0.05	Intelligent platform data statistics
	Classroom interaction participation	0.05	Classroom interaction system record
	Completion status of homework	0.05	AI automatic grading + teacher comments
Comprehensive literacy development	Team collaboration ability	0.05	Group mutual evaluation + teacher evaluation
	Innovative thinking and problem-solving ability	0.05	Comprehensive project assessment + enterprise evaluation
	Learning attitude and professional ethics	0.05	Multi-agent comprehensive evaluation

Table 1. Evaluation Indicator System for Smart Teaching of PLC Courses

5. Teaching experiment and effect analysis

5.1. Experimental design

5.1.1. Experimental subject

Two classes from the 2023 grade of the Electromechanical Major at Lanzhou Modern Vacational College were selected as the research subjects. The experimental class (40 students) adopted an AI-empowered smart teaching model, while the control class (43 students) followed the traditional teaching approach. There were no significant differences (P>0.05) between the two classes in terms of entrance exam scores, cognitive levels, and learning foundations, making them comparable.

5.1.2. Experimental period

The experimental period lasts for one semester (18 weeks), with 4 class hours per week, totaling 72 class hours.

5.1.3. Experimental variable

Independent variable: Teaching mode (Smart teaching mode vs Traditional teaching mode)

Dependent variables: students' PLC course academic performance, skill operation

ability, learning attitude, and satisfaction;
Control variables: textbooks, teaching content, class schedule, teachers, assessment criteria, etc.

5.2. Experiment implementation

5.2.1. Experimental Class Implementation

The experimental class follows the AI-empowered 9+9 dual-process intelligent teaching model for instruction. It primarily utilizes an intelligent teaching platform for pre-class preview and learning analysis, employs a virtual simulation system for immersive practical training, adopts AI teaching assistants for personalized tutoring and answering questions, and completes teaching evaluation and feedback through a diversified evaluation system.

5.2.2. Control group implementation

Adopting the traditional teaching mode of "theory explanation - demonstration operation - student imitation - final assessment", the teaching content is consistent with that of the experimental class, but without the use of artificial intelligence-related teaching tools and methods.

5.3. Experimental results and analysis

5.3.1. Knowledge mastery dimension: dual improvement of process and outcome data

The knowledge mastery dimension encompasses both process indicators during pre-class and in-class activities, as well as outcome indicators from the final written exam. Data reveals that the experimental class exhibits significantly higher rates of preview completion, test accuracy, and passing rates in classroom assessments compared to the control class. Additionally, the average score in the final written exam is 12.5 points higher, with a 100% pass rate and a 20 percentage point increase in the excellent rate, confirming the promotional effect of this intelligent teaching model on students' mastery of PLC theoretical knowledge.

evaluation phase	class	number of people	theoretical score	skill score	total score	t-value	P-value
midterm exam	Experimental Class	40	78.6±8.2	76.3±9.1	77.5±8.5	3.862	0.000
	control class	43	71.2±9.5	68.5±10.3	70.0±9.8	3.547	0.001
final exam	Experimental Class	40	82.4±7.6	83.7±8.5	83.1±7.8	4.638	0.000
	control class	43	73.5±8.9	72.3±9.7	72.9±9.2	5.219	0.000

Table 2. Comparison of academic performance between two classes of students (mean ± standard deviation)

5.3.2. Learning attitude dimension: significant enhancement in active participation

The learning attitude dimension is measured from three aspects: classroom interaction, self-planning, and teaching satisfaction. In the experimental class, the number of classroom interactions and participation rates increased by 70.8% and 42 percentage points respectively, and the proportion of students formulating self-learning plans increased by 38 percentage points. 83.78% of students supported the smart classroom, and 92.3% expressed satisfaction with the teaching, which were significantly higher than those in the control class, reflecting an enhancement in students' active participation.

5.3.3. Teaching efficiency dimension: Effective reduction of teachers' workload

The teaching efficiency dimension focuses on changes in teachers' workload. Teachers in the experimental class reduced their lesson preparation time by 1.1 hours per class, resulting in a 30.6% increase in lesson preparation efficiency. AI automatic grading reduced the time spent on grading homework and tests by 1 hour per class, resulting in a 45.5% increase in efficiency. AI learning analysis also significantly shortened the time it took for teachers to identify common problems, fully verifying the practical value of this teaching model.

6. Conclusions and Prospects

6.1. Research findings

This study addresses the pain points in PLC course teaching in vocational schools, and with the support of three major learning theories, constructs and validates the "AI-Empowered 9+9 Dual-Process Smart Teaching Model". This model features dual-process collaboration, full AI integration throughout the entire process, and process-based evaluation. It has achieved significant results in the four dimensions of knowledge, skills, attitudes, and efficiency. It is innovative and scalable, providing a reference for the smart reform of similar courses.

6.2. Research Prospects

Future research can expand the scope of study by applying this intelligent teaching model to other professional courses in electromechanical fields to verify its versatility and adaptability. It is also necessary to strengthen the research on the application of large AI models in teaching, develop more intelligent teaching assistants and personalized learning systems, conduct long-term follow-up studies to analyze the long-term impact of the model on students' career development, explore deeper integration paths for "AI + vocational education", and build a more comprehensive intelligent teaching system to provide stronger support for the digital transformation of vocational education.

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