World Journal of Education and Humanities
ISSN 2687-6760 (Print) ISSN 2687-6779 (Online)
Vol. 7 No. 5, 2025
www.scholink.org/ojs/index.php/wjeh

Original Paper

Research on the Construction and Application of High-Quality Online Open Courses in Higher Vocational Colleges

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Received: August 08, 2025 Accepted: September 28, 2025 Online Published: October 11, 2025
doi:10.22158/wjeh.v7n5p27 URL: http://dx.doi.org/10.22158/wjeh.v7n5p27

Abstract

With the rapid development of digital education, the construction of high-quality online open courses has become an important direction for educational reform in higher vocational colleges. Taking the Mobile Network Fundamentals Practice course as an example, this study explores the construction and application pathways of high-quality online open courses based on the concept of competency-oriented education. Through university-enterprise cooperation, resource integration, and curriculum reconstruction, the study aligns course content closely with industry standards and job requirements, building a student-centered and ability-oriented teaching system. By employing big data and artificial intelligence technologies, the study enables precise analysis and dynamic optimization of the teaching process, thereby improving course quality and learning outcomes. Through project-based task design, diversified teaching methods, and multi-dimensional evaluation systems, this research demonstrates that competency-oriented online open courses significantly enhance students' professional literacy, innovation capacity, and employability. The findings provide a replicable model and valuable insights for promoting digital transformation and high-quality curriculum development in vocational education.

Keywords

Higher vocational colleges,competency-oriented education, high-quality online open courses, digital education, university-enterprise cooperation, teaching model, artificial intelligence

1. Introduction

1.1 Research Background

In the era of digital transformation, online education has become a critical driver of pedagogical innovation and resource sharing. Within this context, high-quality online open courses (QOOCs) have emerged as an essential means of improving teaching quality and expanding equitable access to education. Since the launch of China's National Quality Open Course Initiative in 2017, vocational education institutions have increasingly emphasized the integration of digital technologies into teaching. This trend aligns with the Opinions on Deepening the Reform of the Modern Vocational Education System issued by the State Council in 2022, which highlights the importance of developing premium online courses and digital learning resources.

Higher vocational colleges, positioned at the intersection of education and industry, play a pivotal role in cultivating technically skilled professionals. However, traditional teaching models in vocational education often face challenges such as limited interactivity, insufficient connection between curriculum content and job requirements, and the lack of scalable digital learning platforms. The development of competency-oriented high-quality online open courses provides a viable solution to these issues, promoting flexible, personalized, and industry-linked learning experiences. By leveraging digital platforms such as Smart Tree (Zhihuishu), vocational institutions can extend learning beyond the physical classroom, enabling continuous, autonomous, and collaborative learning for students, as well as lifelong upskilling for working professionals.

1.2 Significance of the Study

This research holds both theoretical and practical significance. Theoretically, it deepens the understanding of competency-oriented education within the context of online learning by integrating the principles of constructivism, blended learning, and digital pedagogy. The study also provides a systematic framework for designing and evaluating online courses that align with vocational skills standards and industry requirements.

Practically, this study aims to enhance the quality, relevance, and effectiveness of online teaching in higher vocational colleges. By aligning course content with workplace competencies, it addresses the gap between classroom learning and practical job performance. The integration of big data and artificial intelligence technologies into course management enables dynamic tracking of student engagement, personalized feedback, and continuous optimization of teaching strategies. Furthermore, the construction of a scalable QOOC model benefits not only enrolled students but also external learners—including employees, trainees, and individuals pursuing continuing education—thereby contributing to lifelong learning ecosystems and regional industrial development.

In summary, this study contributes to the transformation of traditional vocational education toward digital, intelligent, and competency-driven teaching paradigms. It provides replicable experiences and data-based evidence for promoting innovation in China's higher vocational education system.

1.3 Research Objectives

The primary objective of this research is to explore effective strategies for the construction and application of competency-oriented high-quality online open courses in higher vocational colleges. Specifically, the study aims to:

(1) Construct a competency-based course design model that integrates job requirements, learning outcomes, and curriculum objectives;
(2) Develop a digital course framework that combines theoretical learning, practical application, and AI-supported learning analytics;
(3) Apply big data and artificial intelligence to monitor student performance and learning engagement, providing feedback for course improvement;
(4) Establish a diversified evaluation system that includes process, summative, and value-added assessment indicators;
(5) Validate the model through practical implementation, using the Mobile Network Fundamentals Practice course as a case study to demonstrate how QOOCs can enhance students' learning motivation, technical competency, and employability.

Through these objectives, the study seeks to promote the modernization of vocational education by fostering synergy between education, industry, and technology, offering a sustainable pathway for the development of high-quality online learning in the vocational sector.

2. Theoretical Framework and Literature Review

2.1 Definition and Characteristics of High-Quality Online Open Courses

High-quality online open courses (QOOCs) are digitally delivered learning modules that integrate instructional design, multimedia technology, and pedagogical innovation to provide equitable, accessible, and scalable education for diverse learners. The core characteristics of QOOCs include openness, interactivity, modularity, and quality assurance. Unlike traditional online courses, QOOCs emphasize learning experience, pedagogical innovation, and professional competency development rather than simple content delivery.

From a theoretical standpoint, QOOCs embody the principles of constructivist learning, which highlight learner-centered knowledge construction through active engagement, collaboration, and reflection. Additionally, QOOCs typically integrate multi-modal learning resources—such as video lectures, simulations, quizzes, discussion forums, and AI-driven feedback systems—to support individualized learning paths. They also employ data-driven analytics to assess student progress and adapt teaching content dynamically.

In vocational education, QOOCs have a dual function: they serve as a platform for professional skill acquisition and as a bridge between academic instruction and industry practice. Therefore, their quality is determined not only by academic rigor and content richness but also by relevance to real-world competencies, adaptability to job requirements, and sustainability through continuous improvement mechanisms.

2.2 The Concept of Competency-Oriented Education

Competency-oriented education (COE) is an instructional approach that focuses on the development of practical skills, applied knowledge, and professional attitudes necessary for successful job performance.

Unlike traditional outcome-based education, COE places occupational competency—the ability to apply knowledge effectively in real workplace scenarios—at the center of the teaching and learning process.

The theoretical foundation of COE can be traced to Bloom's taxonomy and constructivist learning theory, emphasizing cognitive, affective, and psychomotor dimensions of learning. In the context of vocational education, COE promotes a "learning by doing" paradigm, where learning tasks are structured around authentic professional activities.

Key features of COE include:

(1) Alignment of curriculum objectives with industry standards and job descriptions;

(2) Integration of project-based and task-driven learning;

(3) Implementation of multi-dimensional assessment systems covering both formative and summative evaluation;

(4) Focus on lifelong learning and employability enhancement.

In the digital era, the combination of COE and QOOCs offers a transformative model for vocational education, enabling flexible, self-directed, and competency-based learning supported by online technologies.

2.3 Digital Transformation in Vocational Education

The digital transformation of vocational education refers to the comprehensive application of information technology, big data, and artificial intelligence to modernize educational content, delivery, and management. This transformation is reshaping how teachers teach, how students learn, and how skills are certified and recognized.

In China, policy frameworks such as the Modern Vocational Education Reform Plan (2022) and Artificial Intelligence Plus Action Plan (2024) have accelerated this shift by encouraging the construction of digital learning platforms, smart classrooms, and online resource repositories. Through the use of cloud computing, real-world practice, and AI-assisted tutoring, digital transformation supports personalized learning trajectories, adaptive assessments, and real-time analytics of learning behavior.

Empirical data further validates this transformation: according to the China Vocational Education Digitalization Report (2023), over 68% of higher vocational institutions have established online learning platforms, and over 80% of teachers have participated in digital pedagogy training. Meanwhile, student engagement rates in blended or online courses increased by 35% compared with traditional classroom models.

The digital transformation process, however, also faces challenges such as uneven resource allocation, limited teacher ICT competence, and the lack of unified quality evaluation standards for online vocational courses. Addressing these gaps requires integrating technological innovation with educational theory, and ensuring that digital tools genuinely enhance—rather than replace—the human-centered nature of teaching.

2.4 Review of Domestic and International Research

Internationally, the development of online open courses has evolved rapidly since the introduction of MOOCs by institutions such as Stanford, Harvard, and MIT. Scholars including Downes (2019) and Siemens (2020) have argued that the success of MOOCs depends on learner autonomy, community interaction, and network-based learning structures. Later models such as SPOCs (Small Private Online Courses) and Micro-Credentials further refined course quality and professional recognition, emphasizing skills alignment with labor market needs.

Domestically, Chinese researchers have localized these ideas within the vocational education framework. Li Hua (2021) and Zhang Linlin (2023) highlight that high-quality online open courses in China must be guided by "industry-driven, ability-oriented, and technology-supported" principles. Research also indicates that integrating enterprise projects into course design enhances students' problem-solving skills and strengthens their professional identity (Yang & Zhao, 2022).

Nevertheless, current domestic literature identifies persistent issues: inadequate integration between digital platforms and teaching objectives, insufficient application of big data for instructional feedback, and limited participation of industry experts in course development. This study contributes to closing these research gaps by combining competency-based pedagogy, AI-driven learning analytics, and industry collaboration into a comprehensive model for QOOC development and application in higher vocational education.

3. Methodology

3.1 Research Design

This study adopts a mixed-method research design, combining quantitative data analysis with qualitative observation and feedback to ensure a comprehensive evaluation of the construction and application of high-quality online open courses (QOOCs) in higher vocational education.

The overall design is structured in three key stages:

(1) Course Construction Stage—The Mobile Network Fundamentals Practice course was reconstructed based on the competency-oriented framework. Industry standards, job tasks, and skill modules were mapped to specific course objectives and digital resources.

(2) Implementation Stage—The course was launched on the Smart Tree (Zhihuishu) platform for one academic year. Both enrolled and external learners participated, and real-time data were collected regarding engagement, completion, and learning behavior.

(3) Evaluation and Optimization Stage—Quantitative analysis using big data metrics and AI-driven insights was conducted to evaluate learning effectiveness. Qualitative data, including learner feedback and instructor reflections, were used to refine teaching content and strategies.

The methodological approach emphasizes practical validation, reflecting the dual characteristics of vocational education—application and skill orientation. The research design follows the "Design–Implement–Evaluate–Iterate" model, ensuring continuous course improvement and sustainable educational outcomes.

3.2 Data Collection and Analysis

Data for this study were obtained from three major sources:

(1) Learning Analytics Data—Automatically collected from the Smart Tree platform, including login frequency, time-on-task, quiz performance, and forum activity.

(2) Questionnaires and Feedback Forms—Administered to both students and teachers to gather subjective perceptions regarding learning motivation, platform usability, and teaching satisfaction.

(3) Performance Records and Assessment Results Derived from the course's internal grading system, covering formative and summative evaluation metrics.

Quantitative data were analyzed using descriptive statistics (mean, standard deviation, frequency distribution) and correlation analysis to explore relationships between learning engagement and performance. Qualitative data from interviews and open-ended responses were analyzed using content analysis to identify recurring themes related to student experience, instructional challenges, and pedagogical impact.

A triangulation approach was applied to ensure data reliability, combining behavioral data, evaluative results, and user perceptions. This method allowed for a holistic understanding of how QOOCs influence learners' skill development and motivation within a competency-oriented framework.

3.3 Application of Big Data and AI in Course Evaluation

The integration of big data analytics and artificial intelligence (AI) technologies played a central role in this study's evaluation process. The Smart Tree platform's data-driven infrastructure enabled continuous monitoring of student activities and performance metrics in real time.

AI algorithms were employed for three key functions:

(1) Learning Behavior Analysis—Machine learning models classified students into engagement clusters (active, moderate, and passive learners) based on activity logs and participation frequency.

(2) Adaptive Feedback Generation—Natural language processing (NLP) tools analyzed student comments and automatically generated targeted feedback or supplementary resources.

(3) Predictive Learning Analytics—Regression and clustering models predicted performance trends and dropout risks based on cumulative behavioral and assessment data.

The overall learning effectiveness (E) of the course was evaluated using a weighted linear model, which integrates performance, interaction, and satisfaction indicators:

Formula (1): Learning Effectiveness Evaluation Model $E=\alpha \mathrm{P}+\beta I+\gamma S$

where:

E—Learning effectiveness index (0–100 scale);

P—Performance score based on assignments, quizzes, and final exams;

I—Interaction index reflecting participation in discussions and peer evaluations;

S—Satisfaction level derived from feedback surveys;

α,β,γ— Weight coefficients empirically determined as 0.5, 0.3, and 0.2 respectively.

This model allowed the research team to quantify the multidimensional aspects of learning quality, emphasizing not only academic achievement but also engagement and emotional investment—key indicators of vocational competence development.

3.4 Research Hypothesis

Based on the literature review and theoretical framework, the study formulated the following hypotheses to guide data collection and analysis:

(1) H1: Competency-oriented course design has a positive effect on learners' engagement and motivation in online vocational education.

(2) H2: The integration of big data and AI-driven feedback mechanisms significantly improves overall learning effectiveness ((E)) compared to traditional online courses.

(3) H3: Learners participating in QOOCs demonstrate higher levels of job-related competency development than those in conventional classroom-based instruction.

(4) H4: A diversified evaluation system—including formative, summative, and value-added assessments—enhances students' self-regulated learning and practical skill acquisition.

(5) H5: The synergy between educational institutions and industry partners contributes to the sustainability and scalability of high-quality online open courses.

4. Construction of High-Quality Online Open Courses

4.1 Course Design Principles Based on Competency Orientation

The construction of high-quality online open courses (QOOCs) in higher vocational education is guided by the principle of competency orientation, which prioritizes the cultivation of practical, job-relevant abilities rather than the mere transmission of theoretical knowledge. This principle emphasizes the development of professional competencies, technical proficiency, and lifelong learning capabilities, aligning education with the real needs of the labor market.

In the design of the Mobile Network Fundamentals Practice QOOC, three pedagogical pillars were established:

(1) Learning for employability—Course objectives were derived directly from occupational competency standards, ensuring each learning outcome contributes to employable skill formation.

(2) Learning by doing—Instructional design incorporated project- and task-based modules to engage students in authentic engineering scenarios.

(3) Learning with reflection—Assessment mechanisms and feedback loops encouraged learners to critically evaluate their own learning progress and skill development.

Furthermore, the course design adheres to constructivist educational theory, fostering active participation, collaborative problem-solving, and contextualized learning. This competency-oriented design ensures that each module not only delivers knowledge but also builds the ability to apply it effectively in professional contexts.

4.2 Course Content Framework and Knowledge Structure

The content framework of the QOOC follows a modular and hierarchical structure, enabling progressive skill acquisition and knowledge integration. The course is divided into five interrelated modules—from fundamental concepts to advanced project-based practice—corresponding to the progressive development of occupational competencies.

Each module is structured around a learning objective–task–assessment triad:

(1) Learning Objective: Defines the targeted job-related ability or technical knowledge;

(2) Learning Task: Provides an applied scenario or problem for students to solve;

(3) Assessment: Validates both conceptual understanding and operational performance.

The relationship between modules, competencies, and learning methods is illustrated below.

Table 1. Course Content Structure and Competency Alignment

Module	Main Topics	Core Competency Goal	Learning Method	Assessment Type
Module 1: Fundamentals of Mobile Networks	Principles of wireless communication; network architecture; signal transmission	Understand theoretical foundations of mobile communication systems and network protocols	Video lectures + Interactive quizzes	Online knowledge test
Module 2: Network Equipment Configuration and Testing	Base station setup; router and switch configuration; equipment calibration	Develop operational and troubleshooting skills for mobile network devices	Real-world practice + Practical exercises	Task-based project report
Module 3: Wireless Network Optimization and Data Analysis	5G network optimization; data traffic monitoring; performance analysis tools	Apply analytical skills to evaluate network efficiency and implement optimization strategies	AI-assisted case study + Group discussion	Applied research report
Module 4: Communication Standards and Industry Regulations	National and international communication standards; network safety and	Recognize the importance of regulatory standards, professional ethics, and compliance in	Scenario-based learning + Policy analysis	Written reflection report

	compliance	network engineering		
Module 5: Integrated Project Practice	Comprehensive network design and deployment project	Integrate multidisciplinary knowledge to solve real engineering problems collaboratively	Project-based learning (PBL) + Enterprise mentorship	Project presentation + Peer evaluation

This table outlines the competency-based modular design of the Mobile Network Fundamentals Practice course. Each module is structured to bridge theoretical understanding and practical application, reflecting the essence of competency-oriented education.

① Modules 1–2 emphasize cognitive and operational skill development, building a strong technical foundation.

② Modules 3–4 address analytical and professional competencies, integrating AI-assisted learning and industry compliance.

③ Module 5 serves as a capstone project, fostering teamwork, innovation, and professional identity formation.

Together, these modules demonstrate how the QOOC model systematically cultivates learning-to-know, learning-to-do, and learning-to-be, aligning educational objectives with real-world occupational competencies.

The modularized design facilitates flexible and adaptive learning, allowing students from diverse professional backgrounds to choose suitable learning paths based on prior experience and career orientation. The inclusion of AI-supported learning analytics further enables personalized learning recommendations, aligning study progression with individual competency development.

4.3 Integration of Industry Standards and Professional Skills

The integration of industry standards and professional skill frameworks represents a key innovation of this QOOC. The course design is closely aligned with 5G communication industry standards, national vocational qualification criteria, and enterprise-level technical specifications.

This alignment was achieved through university–enterprise collaboration with China Communications Construction First Engineering Bureau, whose engineers participated in curriculum co-design, case development, and resource review. Their expertise ensured that course content accurately reflects current technological advancements, operational procedures, and safety regulations within the communication engineering field.

Professional skills addressed in the course include:

(1) Network architecture analysis and configuration;

(2) Signal testing and performance optimization;

(3) Compliance with technical and ethical standards;

(4) Effective communication and teamwork in engineering environments.

By embedding these professional competencies into each module, the QOOC ensures that students acquire not only theoretical knowledge but also transferable workplace skills—bridging the persistent gap between academic learning and professional practice.

Moreover, the assessment system integrates multi-source evaluation, combining self-assessment, peer review, instructor evaluation, and automated feedback generated by AI algorithms. This multidimensional evaluation approach reflects real-world industry assessment mechanisms and enhances the authenticity of the learning experience.

4.4 Development of Multi-Scenario Digital Learning Resources

The QOOC incorporates multi-scenario digital learning resources that support diverse learning modes and learner preferences. This approach addresses the heterogeneity of vocational students and accommodates flexible study patterns for working professionals.

Key digital learning scenarios include:

(1) Multi-Scenario Teaching—The course is delivered in a progressive manner across multiple scenarios, including integration-of-theory-and-practice classrooms, university-enterprise co-built training labs, and real workplaces. Online videos are used to overcome challenges in multi-scenario teaching, ensuring smooth connection between different scenarios, gradual progression of knowledge, and orderly improvement of skills.

(2) AI-assisted Learning—Intelligent tutoring systems provide personalized feedback, progress tracking, and adaptive quizzes based on individual learner profiles.

(3) Collaborative Learning Spaces—Online discussion boards, group projects, and peer evaluations promote teamwork and communication, simulating real enterprise collaboration.

(4) Blended Learning Integration—On-campus workshops complement online modules, reinforcing practical skills through hands-on activities.

Each digital resource was developed following usability, accessibility, and scalability principles to ensure optimal learner engagement and sustained motivation. The inclusion of big data analytics enables continuous improvement—identifying underperforming content, tracking engagement trends, and suggesting pedagogical adjustments.

In sum, the development of multi-scenario digital resources enhances both pedagogical depth and technological interactivity, fostering a learner-centered ecosystem where vocational education becomes more adaptive, data-informed, and industry-relevant.

5. Application and Implementation

5.1 Pilot Application on the Smart Tree Platform

The Mobile Network Fundamentals Practice QOOC was piloted on the Smart Tree (Zhihuishu) learning platform between September 2024 and June 2025. The pilot involved 386 students from the

Communication Technology and Intelligent Engineering programs across three departments, with an additional 110 external learners from partner institutions and enterprises.

The Smart Tree platform was chosen for its comprehensive support of AI-driven analytics, interactive assessments, and multi-terminal access. The pilot phase focused on testing the platform's ability to facilitate large-scale interactive learning and gather real-time behavioral data.

During the pilot, the course modules were released sequentially to maintain logical progression and ensure cognitive scaffolding. Each module integrated multimedia instructional videos and practice assignments. Students were encouraged to engage in weekly discussion forums and complete formative quizzes embedded within each unit.

Data collected from the Smart Tree platform included:

(1) Log-in frequency and session duration;

(2) Completion rates for micro-tasks and module quizzes;

(3) Peer interaction metrics;

(4) AI-evaluated engagement indicators.

The data-driven monitoring of these elements provided valuable insights into learner engagement patterns, allowing the teaching team to identify at-risk students and adapt instructional pacing accordingly. The pilot thus verified the operational feasibility and pedagogical effectiveness of the QOOC model in a real-world educational context.

5.2 Integration of AI-Driven Learning Assistance

A defining innovation of the QOOC implementation lies in the integration of AI-based learning assistance, which personalized the educational experience and enhanced instructional precision.

The Smart Tree platform utilized intelligent learning algorithms that analyzed learners' behaviors and generated adaptive learning paths. Based on students' quiz results, interaction frequency, and engagement time, the AI system automatically recommended supplementary learning materials, re-practice exercises, or targeted mini-tests.

Furthermore, AI teaching assistants were employed to provide real-time feedback and automated grading for objective-type assessments. For open-ended responses, NLP (Natural Language Processing) tools were used to evaluate key terms and conceptual accuracy, offering automated hints and feedback loops.

Teachers benefited from AI dashboards that visualized each learner's progress and provided predictive alerts about disengagement risks. This data-informed teaching ecosystem transformed the educator's role—from traditional knowledge deliverer to strategic learning facilitator.

The integration of AI also reduced teacher workload while improving the accuracy and timeliness of academic feedback, reinforcing the interactive and competency-based nature of the online learning experience.

5.3 Teaching Evaluation and Continuous Improvement Mechanism

Teaching evaluation in the QOOC pilot followed a three-dimensional structure—comprising process evaluation, outcome evaluation, and value-added analysis—to ensure comprehensive measurement of learning effectiveness and instructional quality.

(1) Process Evaluation:Focused on engagement metrics such as attendance, discussion participation, and task completion. This helped measure learning persistence and active involvement.

(2) Outcome Evaluation:Assessed students' mastery of theoretical and technical competencies through graded assignments, quizzes, and final assessments.

(3) Value-Added Evaluation:Compared pre-course and post-course self-assessment data to determine cognitive growth, skill enhancement, and confidence building.

To evaluate the overall effectiveness of the QOOC, both quantitative and qualitative data were analyzed. Quantitative indicators—including course completion rates, satisfaction scores, and certification results—are summarized below.

Table 2. Data Analysis of Course Application Results

Indicator	**Before Implementation (Traditional Course)**	**After Implementation (QOOC-Based Course)**	**Growth Rate (%)**	**Interpretation**
Course Completion Rate	72.50%	91.30%	25.9	The completion rate significantly increased due to flexible learning schedules and AI-driven reminders that enhanced student persistence.
Student Satisfaction (5-point scale)	3.8	4.6	21.1	Improved satisfaction resulted from higher interactivity, rich multimedia content, and personalized feedback mechanisms.
Active Learning Time (hours per week)	2.1	3.7	76.2	Learners spent more time engaging with course materials owing to gamified elements and project-based assignments.
Forum Participation (average posts per student)	1.8	4.9	172.2	A sharp increase in forum engagement indicates stronger peer collaboration and social learning interaction.
Average Quiz Score	74.2	86.5	16.6	Enhanced learning outcomes reflect deeper understanding facilitated by AI-generated

				question banks and adaptive practice modules.
Industry Certification Pass Rate	64.00%	82.00%	28.1	A measurable rise in professional certification success demonstrates improved alignment between course content and job competency requirements.
Teacher–Student Interaction Frequency (per session)	2.3	5.8	152.2	Digital learning analytics allowed instructors to identify at-risk learners and provide targeted support, fostering stronger academic relationships.

This data table demonstrates the quantitative impact of implementing the competency-oriented QOOC model. Key indicators—including completion rate, engagement, and academic performance—show consistent upward trends. The most remarkable improvements appear in forum participation and teacher–student interaction frequency, highlighting how AI-based analytics and adaptive learning tools effectively foster active learning behaviors.

Overall, these findings validate that the integration of digital pedagogy, AI-assisted feedback, and competency-oriented design leads to measurable improvements in both learning quality and vocational readiness. The results also reinforce the scalability potential of QOOCs as a sustainable innovation model for digital transformation in higher vocational education.

The data reveal substantial improvement across all metrics. Completion rates rose from 72.5% to 91.3%, while average quiz scores increased from 74.2 to 86.5. Notably, forum participation tripled, indicating a significant enhancement in student engagement and peer interaction.

Following this quantitative evaluation, qualitative feedback from students confirmed high satisfaction levels with the modular learning structure, AI-based feedback, and multi-scenario practice opportunities. Teachers also noted a marked reduction in classroom management burdens, allowing more focus on personalized guidance and skill-based instruction.

The continuous improvement mechanism adopted a “data–reflection–optimization” loop, ensuring iterative updates to course content, difficulty calibration, and AI-driven task allocation. This cyclical process transformed the course from a static resource to a living digital ecosystem, continuously evolving through feedback and evidence.

5.4 Cross-Institutional and Enterprise Application

Building upon the success of the pilot implementation, the QOOC model has been scaled to multiple institutions and enterprises, illustrating its adaptability and real-world relevance.

Partner institutions—including vocational colleges in Sichuan, Chongqing, and Guizhou—have integrated the Mobile Network Fundamentals Practice course into their core communication engineering curricula. Each institution was granted access to the Smart Tree platform, enabling cross-campus collaboration and shared digital learning ecosystems.

Simultaneously, the course was deployed in collaboration with China Communications Construction First Engineering Bureau, where it was used as a training module for entry-level engineers and technicians. The enterprise application demonstrated the flexibility of QOOCs in professional upskilling and lifelong learning contexts.

This dual-track application—academic and corporate—reflects the "education–industry–technology synergy" that underpins the QOOC model. It promotes the integration of academic knowledge with professional practice, supports lifelong learning pathways, and contributes to the digital transformation of vocational education.

The scalability of the model lies in its modular construction, competency-based evaluation, and AI-enhanced learning analytics. Collectively, these features ensure that the QOOC approach can be replicated, localized, and continually improved across diverse educational and industrial settings.

6. Evaluation and Discussion

6.1 Quantitative Analysis of Learning Outcomes

The implementation of the Mobile Network Fundamentals Practice QOOC demonstrated clear quantitative improvements in multiple dimensions of learning effectiveness. Based on platform analytics and course assessment data, measurable gains were observed across completion rates, engagement levels, academic performance, and satisfaction scores.

Statistical analysis revealed a 19% increase in course completion rates, accompanied by a substantial rise in quiz and project scores. The average final score improved from 74.2 to 86.5, suggesting that the competency-oriented instructional approach effectively enhanced both cognitive understanding and applied technical proficiency.

Behavioral data further indicated significant improvement in student engagement. Average weekly active learning time increased from 2.1 to 3.7 hours, and discussion forum participation rose by 172%, reflecting higher motivation and collaboration. Correlation analysis ($r = 0.68$, $p < 0.01$) showed a strong positive relationship between forum activity and final course scores, supporting the hypothesis that interactive learning behaviors strongly influence academic achievement.

These findings quantitatively validate the efficacy of the QOOC model in promoting sustained engagement, autonomous learning, and competency acquisition, surpassing traditional lecture-based pedagogies in vocational education settings.

6.2 Qualitative Feedback from Students and Instructors

Qualitative feedback collected through semi-structured interviews and online surveys provided deeper insights into the perceived value and practical impact of the QOOC.

Students' Perspectives:

Most learners appreciated the flexibility and accessibility of the online course, noting that the modular structure allowed them to "learn anytime and anywhere." Many highlighted that the project-driven learning model improved their problem-solving ability and confidence in applying theoretical concepts to real-world tasks. The inclusion of AI-based feedback tools was frequently praised for helping learners identify weaknesses early and make targeted improvements.

Representative student comments included:

“Skill demonstrations and real-world scenario presentations make understanding complex network concepts easier.”

“I liked how the course linked each topic to actual job tasks—it felt more meaningful than a traditional lecture.”

Instructors’ Perspectives:

Teachers reported that AI analytics dashboards and automated grading significantly reduced administrative workload, allowing them to focus more on mentoring and individualized support. Several instructors noted a “positive behavioral shift” among students, observing higher attendance, deeper discussions, and stronger motivation.

One instructor summarized:

“The QOOC model transformed teaching from delivering content to facilitating learning—it made me rethink how students build professional competence.”

Collectively, this qualitative evidence affirms that both students and teachers recognize the transformative pedagogical and motivational benefits of the QOOC model.

6.3 Advantages of the Competency-Oriented Approach

The integration of competency-oriented pedagogy within a digital learning ecosystem proved to be the cornerstone of the course’s success. The approach offered several distinct advantages:

(1) Alignment with Industry Needs:By anchoring learning objectives in occupational competency standards, the course ensured direct relevance to professional roles such as 5G network technician and wireless systems engineer. This alignment enhanced both career readiness and employability.

(2) Active and Experiential Learning:The task-driven and project-based design encouraged students to learn through doing, bridging the traditional divide between theory and practice. This experiential focus nurtured problem-solving, teamwork, and decision-making skills, key attributes in technical professions.

(3) Data-Driven Personalization:The integration of AI allowed for continuous tracking of learning behaviors and outcomes. Students received personalized learning recommendations, while instructors accessed real-time diagnostic insights, enabling dynamic instructional adjustments.

(4) Scalable Quality Assurance:Standardized digital modules, automated evaluation, and big-data-supported performance tracking provided a scalable framework for maintaining instructional quality across different institutions and learner cohorts.

(5) Promotion of Lifelong Learning:The QOOC’s open-access structure supported ongoing professional development, allowing learners beyond the academic setting—including enterprise trainees—to engage in continuous skill upgrading.

In essence, the competency-oriented QOOC transcended the limitations of conventional teaching, fostering autonomous, reflective, and career-oriented learning in vocational education.

6.4 Challenges and Improvement Suggestions

Despite its demonstrated success, the QOOC implementation revealed several challenges requiring strategic refinement to ensure long-term sustainability and broader adoption.

(1) Uneven Digital Literacy Levels:A subset of students struggled to fully utilize online tools due to insufficient digital skills. Future courses should include introductory digital literacy modules or AI-assisted onboarding tutorials to support these learners.

(2) Limited Instructor Training in AI Pedagogy:While the integration of intelligent teaching assistants enhanced efficiency, not all instructors were proficient in leveraging AI analytics effectively. Regular faculty development programs focused on AI-enhanced teaching strategies are essential to improve instructional competence.

(3) Resource Development Workload:High-quality multimedia resource production (e.g., Operation Demonstration, videos, animations) remains time- and cost-intensive. A sustainable solution involves establishing cross-institutional resource-sharing alliances to jointly develop and maintain QOOC content libraries.

(4) Data Privacy and Ethical Concerns:As big data and AI technologies become increasingly embedded in education, institutions must ensure robust data protection mechanisms and transparent ethical governance regarding learner analytics.

(5) Need for Broader Industrial Collaboration:Although the pilot involved one corporate partner, expanding the model to a wider industry network would enhance diversity in project content and real-world applicability, further strengthening the integration between learning and practice.

7. Conclusion and Recommendations

7.1 Summary of Research Findings

This study explored the construction and application of competency-oriented high-quality online open courses (QOOCs) in higher vocational colleges, using the Mobile Network Fundamentals Practice course as a representative case. Through comprehensive design, implementation, and evaluation, the research achieved multiple key findings.

First, the QOOC model successfully bridged theoretical learning and professional practice, transforming the traditional instructional paradigm into a student-centered, task-driven, and technology-supported ecosystem. The integration of project-based learning and industry collaboration enhanced learners' technical competence and job readiness.

Second, the use of big data analytics and AI-assisted teaching tools effectively improved the precision of instructional feedback and adaptive learning support. Students demonstrated higher engagement levels, longer study durations, and stronger learning motivation.

Third, empirical evidence showed significant improvements across all major learning indicators.

Course completion rates increased by nearly 26%, quiz scores improved by 16%, and student satisfaction rose by over 20%. These quantitative outcomes were reinforced by qualitative feedback highlighting improved self-directed learning, collaborative participation, and professional awareness.

Collectively, the study confirms that competency-oriented QOOCs represent a sustainable and scalable model for the modernization of vocational education, contributing directly to national goals of educational digitalization and lifelong learning.

7.2 Theoretical Contributions

This research makes several important theoretical contributions to the field of educational technology and vocational pedagogy:

(1) Integration of Competency-Based Education and Digital Pedagogy:The study extends the theoretical boundaries of competency-based education (CBE) by embedding it within the context of large-scale digital learning. It establishes a framework that links learning outcomes, job standards, and digital instructional design.

(2) Construction of an Evaluation Model for Online Learning Effectiveness:The study introduced a measurable formula for learning effectiveness

$$E=\alpha \mathrm{P} + \beta I + \gamma S$$

which integrates performance, interaction, and satisfaction dimensions. This model provides a theoretical tool for assessing the multidimensional impacts of online courses beyond simple academic achievement.

(3) Empirical Validation of AI-Supported Learning in Vocational Contexts:Unlike prior theoretical discussions of digital learning, this study demonstrates empirically that AI-assisted feedback and data-driven personalization can significantly enhance both teaching efficiency and student competency development in applied technical disciplines.

(4) Framework for the “Education–Industry–Technology” Synergy:The research proposes a holistic conceptual model for the collaboration between educational institutions and enterprises in digital learning environments, offering theoretical insights into how learning ecosystems evolve under the influence of technological intelligence.

7.3 Practical Implications for Vocational Education Reform

The findings of this research carry profound practical implications for the ongoing reform and digital transformation of vocational education in China and beyond:

(1) Curriculum Reform and Innovation:The competency-oriented QOOC framework provides a replicable blueprint for redesigning vocational curricula to align with real industry needs. Institutions can adopt similar modular structures, integrating theoretical, operational, and reflective learning components.

(2) Teacher Development and Role Transformation:The study underscores the need to redefine the teacher’s role from a knowledge transmitter to a learning facilitator and data-informed mentor. Continuous professional training in AI-assisted pedagogy and digital resource development will be

essential.

(3) Expansion of Lifelong Learning Opportunities:By enabling open access to high-quality resources, QOOCs support both full-time students and working professionals, facilitating lifelong and ubiquitous learning pathways across educational and enterprise environments.

(4) Policy and Institutional Support:The results highlight the importance of policy frameworks that incentivize digital innovation and cross-institutional collaboration. Educational authorities should establish funding and recognition mechanisms to support QOOC development and maintenance.

(5) Quality Assurance through Learning Analytics:The implementation of big data and AI technologies creates a foundation for continuous quality monitoring. Institutions should leverage learning analytics to enhance transparency, accountability, and evidence-based decision-making in education management.

7.4 Limitations and Future Research Directions

While the study achieved meaningful outcomes, several limitations suggest avenues for future research and improvement:

(1) Limited Generalizability of Findings:The empirical data were collected from a single course and institution, which may limit the applicability of results to other disciplines or educational settings. Future studies should involve multi-institutional and cross-regional comparisons to strengthen generalization.

(2) Short-Term Evaluation Window:The evaluation focused on immediate learning outcomes. Longitudinal studies tracking post-course employment performance and skill retention are needed to assess long-term competency development.

(3) Dependence on Platform-Specific Features:The Smart Tree platform's proprietary analytics system may constrain scalability across other digital ecosystems. Future research should explore open-source and interoperable learning platforms to promote universal adoption.

(4) Need for Broader AI Ethics and Governance Frameworks:As AI becomes more integrated into education, further studies should examine ethical considerations, such as data privacy, bias mitigation, and algorithmic transparency, to ensure equitable access and responsible innovation.

(5) Exploration of Emerging Technologies:Future work should investigate how extended reality (XR), blockchain-based credentialing, and generative AI could further enrich QOOC interactivity, assessment authenticity, and personalized learning pathways.

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Funding Project: 2024 Sichuan Provincial Educational Information Technology Research Project of the Sichuan Center for Educational Informatization and Big Data—Research on the Construction and Application of High-Quality Online Open Courses in Higher Vocational Colleges: A Case Study of the Mobile Network Fundamentals Practice Course (Project No.: 2024KTPSLX314).