Research on the Digital-Intelligent Reform Path of Higher Vocational College Courses - A Case Study of Building Materials and Testing

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Abstract: With the acceleration of digital-intelligent transformation in the construction industry, the course Building Materials and Testing in vocational colleges faces the new mission of cultivating "digital craftsmen." Based on the characteristics of vocational education, this paper analyzes the pain points of traditional courses in teaching content, practical models, and evaluation systems. In alignment with the Digital Strategy Action Plan for Vocational Education, a digital-intelligent innovation path is proposed, centered on "curriculum content restructuring-teaching model innovation-evaluation system upgrading-faculty capability iteration." By integrating digital tools such as BIM technology and virtual simulation, an integrated smart classroom ecosystem of "teaching, learning, practice, and evaluation" is constructed, achieving deep alignment between the course and the digital transformation of the construction industry. The study validates the significant effects of digital-intelligent reform in enhancing students' professional competencies and educational quality through practical reforms at a vocational college, providing a reference for similar curriculum reforms.

Keywords: Digital-Intelligent Reform; Vocational Education Digitization; Modular Curriculum; Virtual-Real Integration; Competency Profiling

1. Introduction

In the background of pursuing carbon peaking and carbon neutrality goals and new-type urbanization, the construction industry is undergoing a deep and profound transition from "traditional construction" to "intelligent construction". *The construction industry development plan of 14th Five-Year Plan* mention explicitly the industrialization, digitization and intelligentize level need to be significantly improve, and prefabricated building be taking up 30% of the new buildings. As the core curriculum of cultivating building material testing talents, the course Building Materials and Testing undertakes an important mission of industrial upgrading. However, the traditional curriculum and its teaching context lag behind the industrial standards, the outcome of practice teaching depends on physics laboratory, and students' occupational capability do not meet the reality of digital testing demand of the enterprises. In 2022, the Ministry of Education launched the *Digital Strategy Action Plan for Vocational Education*[2], proposing that China will promotes the upgrading and digital transition of vocational education and build an innovative system of integration between digital technology and vocational education. In this context, promoting digital-intelligent reform of curriculum not only required by national strategy, but also act as an vital implement in improving the adaptability of vocational education.

2. The Reality Basis and Core Objectives of Digital-Intelligent Reform of the Course Building Materials And Testing

2.1 Pain Points of Traditional Curriculum Analyses

2.1.1 Teaching content lags behind industrial upgrading

Traditional teaching materials emphasize theory and neglect practice. The few practical testing training courses mainly focus on the basic testing methods of sand, cement, concrete and other traditional materials, with less involvement in new green building materials(such as low carbon steel slag concrete). According to the survey in a certain construction company, the utilization rate of digital testing equipment (such as fully-automatic pressure testing machine and spectrometer) has reached 70% in 2023. However, due to the coverage rate of relevant practical training projects in the course is less than 30%, students need to relearn the operation software of the equipment after employment.

2.1.2 Triple difficulties in practical teaching

Difficulty in the practical teaching in high-risk subjects: harmful substance detection such as asphalt and other experiments involving toxic reagents. Traditional teaching relies on teachers' demonstration, and students lack of hands-on experience;

Difficulty in the share of large equipment: high-precision detection instruments are pricey and rare, resulting in low rotation rate that causes low team training efficiency;

Difficulty in the long-term monitoring: the carbonization test of concrete strength takes 28 days, therefore "data simulation" is often used in classroom teaching instead of real testing process.

2.1.3 The evaluation system lacks the support of process data

Traditional assessments primarily consist of a 60% theoretical written test and a 40% experimental report, which fail to fully reflect students' performance in core job competencies such as inspection of standard procedure, anomaly data analysis, and equipment troubleshooting. A follow-up survey of the 2022 graduates from a vocational college found that companies were only 52% satisfied with students' 'digital data processing skills,' highlighting the gap between course evaluations and job requirements.

2.2 Key Objects of Digital-Intelligent Innovation

2.2.1 Interface with industry standards to build a curriculum content system of “new materials and new technologies”

Integrate GB /T 51435-2021 *Technical Standard for Intelligent Testing of Building Materials* and cutting-edge industry technologies (such as carbon emission calculation methods for building materials, and the application of blockchain in testing data record) into teaching, so that the course content is synchronized with the digital process of enterprise testing positions (sample scanning--warehousing-- intelligent equipment testing--cloud data storage--AI quality analysis).

2.2.2 Create a virtual-real integration practical teaching environment to break free from the limits of time and space

Utilize the digital twin technology to build a virtual simulation training platform for building materials testing, which ensure the safety of high-risk experiment, the cloud applying of large equipment and long-term, real-time monitoring; meanwhile, it connects with the testing data of enterprises, so that students can deal with the testing data in the real production scene and improve their professional competence.

2.2.3 Establish a evaluation model of “whole process and multi-dimension” based on data-driven method

Through intelligent terminals, students' behavior data in virtual simulation, practical training operation, enterprise post and other data are collected, applying learning analysis technology to generate ability portrait, therefore weak links are accurately diagnosed, and "teaching-learning-evaluation" cycle is optimized.

3.Implement and Innovation Strategies of Digital-Intelligent Reform

3.1 Restructuring Course Content: from Fragmented Knowledge to Modular Scenarios

3.1.1 Interface with professional standards and develop “1+N” modular course resources

Based on the professional skill level standards for building material testing technicians, the course is divided into four main modules: 'Basic Testing Technology', 'Application of Intelligent Testing Equipment', 'Green Building Material Testing' and 'Testing Data Management' (see Figure 1). Each module includes four sub-tasks: 'Standard Interpretation', 'Equipment Operation', 'Data Processing' and 'Quality Analysis'. For instance, in the 'Application of Intelligent Testing Equipment' module, a universal testing machine operation simulation system is introduced, along with explanations on equipment network calibration and the automatic uploading of testing data to the BIM platform. This approach ensures that students acquire both equipment operation and digital operation and maintenance skills.

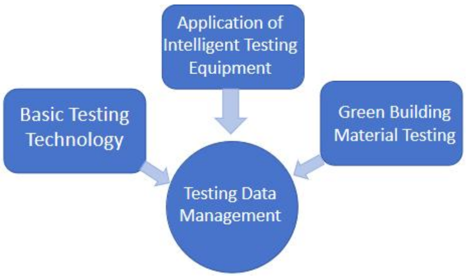

Figure 1. Digital-Intelligent Course Module Structure

3.1.2 Blend in two elements: ideology and political construction and digital literacy

In the Green Building Materials Testing module, combining the General Code for Building Energy Efficiency and Renewable Energy Utilization GB 55015-2021 to explain the supporting role of low-carbon building materials testing for the "double carbon" target and cultivates a green development concept for students; in the Testing Data Management module, students' professional integrity and data security awareness are strengthened through case teaching (such as an engineering accident caused by data falsification in enterprise).

3.2 Innovative Teaching Mode: from "Teacher-Centered" to "Student-Centered"

3.2.1 Build a three-step virtual-real integration teaching system

Stage of virtual cognition: Using Unity 3D to develop a virtual factory for building materials testing. Students can complete the whole process simulation operation from sample receiving, equipment debugging to report generation through software platform, therefore to solve the inefficient problem of "one person operates, many people watch" in traditional teaching [3];

Stage of virtual-real interaction: Deploy intelligent terminals in the physical laboratory. Students scan the QR code to obtain operation guidance, safety notice and historical detection data. If the process of operation is abnormal, the device will automatically trigger the virtual diagnosis system to cultivate emergency handling ability.

Stage of real scenario: To build "cloud training base" with local detection enterprises, and students can analyze as well as process detection data in real time through real situation of production, thus giving process suggestions. Teachers and enterprises mentors can evaluate students' operations through backend(see Figure 2).

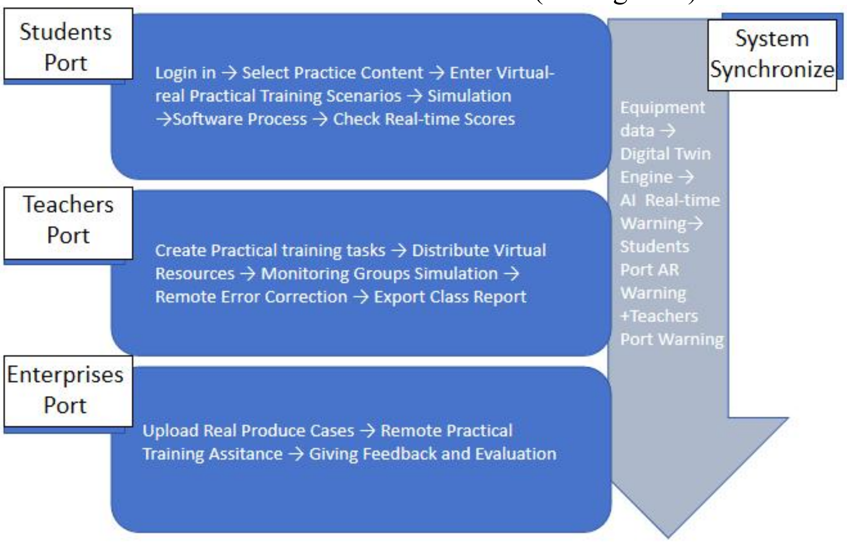

Figure 2. Virtual-Real Practical Training Platform Structure

3.2.2 Apply "task-driven and data visualization" teaching method

In real task of "concrete quality inspection a certain affordable housing project", students work in groups to complete the whole process: formulating an inspection plan, conducting virtual-real rehearsals, performing on spot-building cloud data models and generating quality analysis reports. Students convert inspection data into dynamic charts by software(such as strength growth curves at different period and correlation analysis between mix ratios and strength). Thereby the process can guide students to use SPSS for data significance test, improving their ability of data analysis and decision making.

3.3 Upgrade of Evaluation System: From "Result-Oriented" to "Ability Portrait"

3.3.1 Establish evaluation indicators of "three dimensions and whole process"

Three dimensions include 18 evaluation indicators: "Knowledge and Skills" (including mastery of testing standards and equipment operation norms), "Process and Methods" (such as data processing efficiency and problem-solving skills), and "Professional Ethics" (such as safety awareness and teamwork). The system uses an smart wristband to collect behavioral data, such as the duration of operations and the number of equipment calibrations during practical training. This data is combined with the decision-making paths recorded by the virtual simulation system to generate a comprehensive process evaluation report that integrates multiple sources of data.

3.3.2 Introduce AI intelligent ranking system

Traditional experimental reports involve the issue of subjective scoring errors. Applying the "Gongxueyun" cloud system to automatically evaluate the experiment reports, logical errors(such as data contradictions and inconsistent between conclusions and data) are quickly identified and problems in the reports are formatted, generating improvement suggestions by comparing the excellent report library of the enterprise. After the applying the system, a pilot class's standard compliance rate increased from 68% to 92%, and the teacher evaluation efficiency increased by 40%.

3.4 Enhancing Teachers' Capability: From "Individual Teaching" to "Double Teachers And Double Abilities"

3.4.1 Apply special plan to improve digital competency

In-facility training: invite technicians of equipment company to give lectures about intelligent detection equipment operation and maintenance technology, and assist teachers to use intelligent detection equipment efficiently;

Enterprise practice: teachers should actively participate in the practice of testing institutions or construction enterprises, in real projects, and turn industry cases into teaching resources;

Event-driven: teachers should participate in National Vocational College Skills Teachers' Teaching Competitions, which will promote their ability to integrate the latest technology into the course design.

3.4.2 Build a cooperative teaching team of school and enterprise

Cooperate with local leading testing enterprises to build mobility stations for teachers. Enterprises testing engineers undertake 20% of the practical course and formulate training project scoring standards; Teachers from school participate in enterprise testing technology research(such as the optimization of testing standards for prefabricated building components), forming a virtual interaction between "teaching-learning-evaluation" [4].

4. Practice and Outcome of reform - Take the Building Materials and Testing course of Lanzhou Petrochemical University of Vocational Technology as an example

4.1 Design of Reform Practice Plan

4.1.1 Scope and test period of the pilot class

Pilot class: Two classes in the 2023 level of construction engineering technology major (Experiment group, 42 people) and the traditional teaching model class (control group, 42 people).

Implementation period: September 2023 to January 2024 (one semester).

Technical support: BIM modeling software (Revit), virtual simulation platform (Unity 3D), Internet of Things testing equipment (intelligent pressure testing machine, temperature and humidity sensor), AI review system (Gongxueyun Cloud).

4.1.2 Core reform measures

Virtual-real integration training platform implement:

Build a "smart building materials testing virtual factory", covering 8 types of high-risk experiments(such as asphalt toxicity testing) and 5 types of large equipment operation (such as X-ray fluorescence spectrometer).

Jointly build "cloud testing data center" with enterprises to access real testing data(such as concrete strength monitoring data of an assembled housing project).

4.1.3 Reconstruction of teaching process:

Adopt a "three-step" mode: virtual simulation (20%) →virtual-real collaboration (50%) → real scene (30%).

Taking "concrete durability testing of a bridge project" as the main task, students need to complete the whole process of virtual rehearsal, on-site operation, data modeling and quality analysis.

4.1.4 Upgrade of evaluation system

Deploy including smart wristband, training platform log system, and 18 process indicators including operation standardization (such as the number of equipment calibration times) and data accuracy (such as error range) were collected.

The AI scoring system will automatically analyzes the logic link of the experimental report and compares it with the similarity of the enterprise test report library.

4.2 Implement Process of Key Cases

Example 1: Virtual simulation replacement for high-risk experiments

1)Pain points of traditional courses: the test of asphalt softening point requires the use of high temperature asphalt and toxic reagents. Thus, usually only the teacher can demonstrate, and the practical operation rate of students is less than 10%.

2) Digital-intelligent plan: Using the simulation system, students can complete asphalt heating and penetration test through virtual operation, and the system will provide real-time feedback on potential operation risks. In the real laboratory, safety operation instructions (such as the steps of wearing protective equipment) are added.

3) Outcome:

The participation rate of high-risk experiments increased from 5% to 100%, and the standard compliance rate of operation reached 92%(compared with 78% in the control group). The virtual simulation errors will trigger real-time warning, and the safety accident rate was decreased to zero.

Example 2: Cloud sharing of large equipment

1. Pain points of traditional courses: Only one X-ray fluorescence spectrometer available, as a result, the training of a group of six students takes up four class, with less than 10 minutes of practical operation for one person.

2. Digital-intelligent plan:

Divide the X-ray fluorescence analysis experiment into four sub-tasks: sample preparation, equipment calibration, data acquisition and spectrum analysis. Each group take turns to complete different tasks, reducing the waiting time. Install WIFI module to automatically collect data; apply PGY Intranet penetration tool to synchronize the local database to the public cloud to realize off-campus data access. Enterprises mentors guide the process of data analysis(such as crystal structure diagram interpretation) through online video.

3. Outcome: The utilization rate of X-ray fluorescence spectrometer increased from 15% to 85%, and the actual practical operation time increased to 30 minutes per person at a time.The accuracy rate of students' testing data interpretation increased from 65% to 88%, close to the level of primary inspector in enterprises.

Example3: Visualization of long-term monitoring data

1. Pain points of traditional courses: the carbonization of concrete lasts 28 days, and the classroom can only provide simulate data, so the students lack of real monitoring experience.

2. Digital-intelligent plan: apply rapid-hardening concrete test block(the carbonization period will be shorten to 7 days), combining historical data expansion analysis (such as providing a complete 28-day data set for previous years) to solve the problem of class hour limitation. Students predict the carbonization curve through simulation software, and compare it with actual data to write the carbonization prediction deviation analysis report. Use Python, ImageJ and other tools to help cultivate data process skill and visualization skills. View data changes through mobile terminals, and use Python scripts for trend prediction and abnormal alarm (such as intensity not up to standard).

3. Outcome: The completion rate of long-term monitoring task for students increased from 40% to 95%, and the accuracy of data model(compared with actual data of enterprises) has reached 82%. Enterprises give the feedback: the carbonization analysis report presented by students has the potential to be directly used in the acceptance of work

4.3 Analysis of Reform Outcome

4.3.1 Capability of students have improved significantly

1. Skill mastery (comapred with the control group):

Table 1. Skill Mastery

Index	Experiment Group(%)	Control Group(%)
Standardization of Equipment Operation	92	71
Accuracy of abnormal	86	54

data diagnosis		
Standardization of the test report	94	69

2. Job adaptation rate

After the experimental group students practically participated in the enterprise, the independent operation rate of digital testing equipment reached 100%, and the enterprise satisfaction increased from 52% to 89%.

86% of the students in experimental group passed the intermediate vocational skill level certification of "intelligent testing equipment operator", far exceeding the control group (32%).

4.3.2 Optimization of Teaching Efficiency

Preparation time of teachers is reduced by 30% (Supported by modular resource database and AI assisted tools);

The efficiency of experimental report evaluation increased by 40%, and the personalized feedback rate increased from 20% to 100%.

4.4 Existing Problems and Improvement

4.4.1 Existing challenges

Technology dependence: insufficient funds, construction of the Internet of Things is limited, and the stability of cloud needs to be improved;

Teachers transforming: senior teachers have shown low acceptance rate of smart devices, the cultivation mechanism needs to be strengthened.

4.4.2 Optimization strategies

Develop a light, local version of virtual simulation system to support basic training offline;

Launch the "digital mentor" project, in which enterprise engineers will cooperate with young teachers to accelerate the transition of traditional teachers.

5. Conclusion and Expectation

The digital-intelligent reform of Building Materials and Testing in vocational colleges is essentially to reconstruct the education logic of "Knowledge transmission-skill training-ethic development". The "content reconstruction-mode innovation-evaluation upgrade-teachers transition" four-in-one reform path proposed in this paper not only responds to the new demand for technical and cultivating skilled talents in industrial digitization, but also highlights the trait of vocational education as a type of education. It is essential to further deepen the integration of "AI and education", for example, by exploring the application of blockchain technology in data storage for teaching purposes and immersive practical training models in metaverse scenarios. This will drive vocational college courses reform from 'technology empowerment' to 'ecological restructuring,' aiming to cultivate more new-era craftsmen [5] who are proficient in detection, knowledgeable about digital technology, and skilled in innovation for the construction industry.

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