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Research on the Digital Transformation Path in Engineering Education Based on AI and VR

Bao Cai

School of Intelligent Manufacturing and Control Engineering, Shanghai Polytechnic University, Shanghai 201209, China

Abstract

Under the backdrop of the Ministry of Education's "Education Digitalization Strategy Action," this study uses the Shanghai municipal key course Tolerance, Fit and Technical Measurement as a practical vehicle to construct a new four-dimensional integrated teaching paradigm: "AI Empowerment + Knowledge Graph + Virtual Simulation + Curriculum-based Ideological Education." By integrating the Tencent IMA smart teaching platform, the DeepSeek large model, and VR experimental technology, a smart teaching closed-loop covering the entire "pre-class-in-class-post-class" process was formed. Empirical data shows that this model increased course participation to 98%, improved experiment operation accuracy by 32%, and elevated students' overall scores by an average of 18.7%. This research provides replicable technological pathways and practical case studies for the digital transformation of engineering education.

Keywords

Educational Digitalization; Artificial Intelligence; Knowledge Graph; Virtual Simulation; Tolerance and Fit; Curriculum-based Ideological and Political Education.

1. Introduction

Educational digital transformation has become a strategic direction for global educational development. Minister Huai Jinpeng of the Ministry of Education emphasized at the World Digital Education Conference that digitalization is the key breakthrough point for opening up new tracks and shaping new advantages in education, providing a core platform for cultivating digital-savvy talents and digital craftsmen. Against this backdrop, the course Tolerance, Fit and Technical Measurement, grounded in Shanghai Polytechnic University's talent training orientation of "applied technical talents," closely combines educational digitization trends with OBE engineering certification requirements, aiming to cultivate versatile talents capable of solving engineering problems using digital technologies. As a foundational course for Environmental Protection Equipment Engineering majors, the course has accumulated two years of construction experience as a university-level key course, an AI-supported course, and a curriculum-based ideological education project. It has also received support from the Shanghai Education Science Research Program, possessing solid software and hardware foundations [1].

The course foundation spans five dimensions: First, it leverages the Virtual Simulation and Modern Measurement Laboratories. Second, it features a "four-in-one" characteristic combining "AI Empowerment + Knowledge Graph + VR Experiment + Craftsmanship Spirit Ideological Education." Third, it achieves integration of science, education, and industry through municipal research projects and enterprise horizontal research projects. Fourth, it adopts a student-teacher co-construction model to develop knowledge graph teaching resources, with students achieving awards at municipal academic competitions. Fifth, the teaching team possesses national-level project approval for the "Specialized, Refined, Advanced,

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and New" Industrial College and multiple achievements in Shanghai Municipal Virtual Simulation Projects. These foundations provide technical, resource, and team guarantees for the course's digital transformation[2-3].

2. Research Content

2.1. Course Objectives and Content Restructuring

The course centers on cultivating digital-savvy talents and sets four major competency dimensions: mastering tolerance standards and precision design capabilities; ability to consult and apply national standards and technical drawing annotations; mastering measurement theory and data processing capabilities; evaluating precision design based on social responsibility values. Teaching content is divided into three modules as shown in Fig 1: AI-based teaching based on the IMA platform, visual knowledge graphs, and VR measurement experiments, forming a "learn-practice-assess" closed-loop system. Dimensional tolerance teaching adopts the "Three-Stage Closed-Loop" method (pre-class knowledge base construction, in-class dynamic demonstration, post-class intelligent error management). Geometric tolerance teaching achieves logical visualization through a four-level knowledge framework (root node → leaf node).

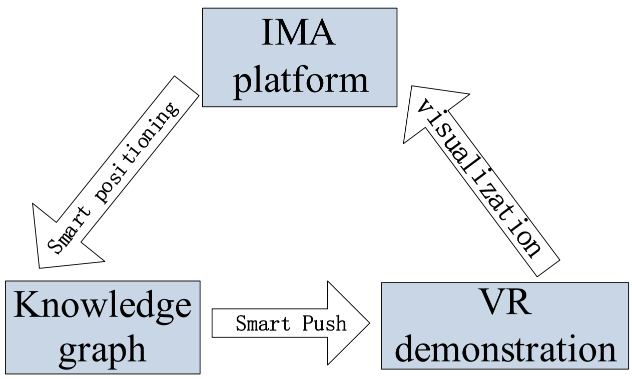

Figure 1. Content Division

2.2. Innovative Intelligent Teaching Methods

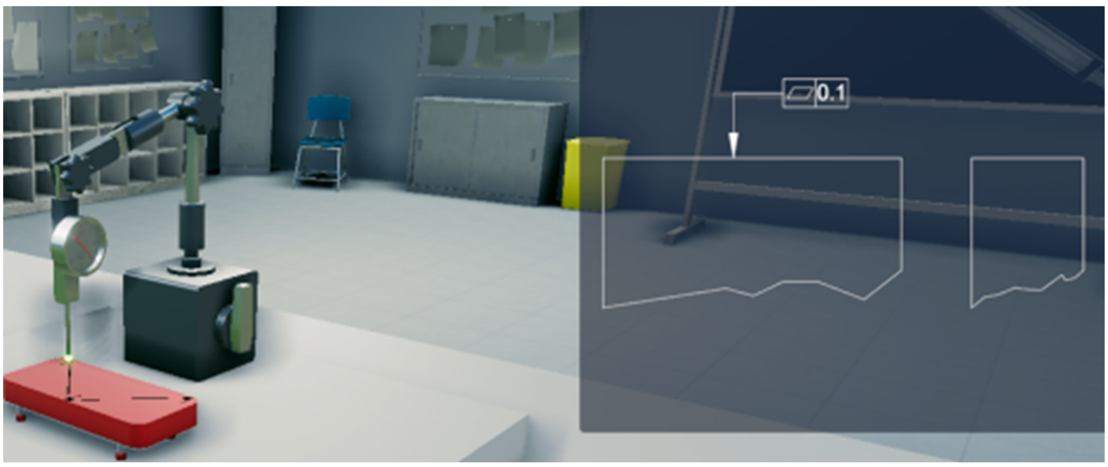

Figure 2. VR Experiment

In terms of AI empowerment, the Tencent IMA platform is used to build a class knowledge base, deeply integrating the course syllabus with private resources (courseware/drawings/national standards), achieving intelligent Q&A, digital whiteboard organization, and VR experiment recommendations. Knowledge graph teaching transforms 19 geometric tolerance features into interactive nodes (e.g., Symmetry tolerance → Gearbox case study), combined with engineering case-driven and hierarchical comparison methods to tackle conceptual abstractions. As shown in Fig 2, VR experiments employ a "Five-Stage Progressive Teaching Method" (Preview → Demonstration → Simulation → Practical Operation → Assessment), developing 16 virtual experiments (e.g., Step shaft inspection). Haptic feedback devices simulate real operations, reducing risks associated with damage to physical equipment.

2.3. Resource Integration and Co-construction

Three types of core resources were developed: First, a dynamic resource library integrated within the IMA platform containing courseware, national standards, enterprise cases, etc. Second, a student-teacher co-constructed knowledge graph, supported by municipal-level innovation projects, mapping logical relationships between knowledge points (the dimensional tolerance chapter contains 32 knowledge points). Third, VR experiment resource packages (including operation of traditional measuring tools and coordinate measuring machines - CMM), totaling over 100 operational steps. Resource development relies on industry-education collaboration (cooperation with Shanghai Aerospace Intelligent Equipment Co.) and education-research collaboration (Shanghai Education Science Research Program), ensuring content aligns with industry needs.

2.4. Ideological Education and Assessment Reform

The integration of the "craftsmanship spirit" into ideological education is implemented through an immersive design called "Meet the Light, Pursue the Light, Become the Light": introducing a case base of "Shanghai Craftsmen" (post-80s generation), linking precision measurement technology with professional ethos. The assessment adopts a process- and competence-oriented model: Total score = Midterm (20%) + Experiments (20%) + Final (60%). The experiment assessment relies on the VR system to generate operational evaluation reports, while the midterm focuses on non-standardized design problems. Post-reform, student performance significantly improved (final exam average scores increased by 22%), confirming the effectiveness of digital methods in enhancing learning outcomes.

As shown in Fig 3, the chart comparing student average scores before and after course reform shows that among the 22nd cohort (n=55) and 23rd cohort (n=59), with comparable sample sizes, students demonstrated significant improvements in classroom performance, in-class assignments, practical experiments, and final exams, fully demonstrating the effectiveness of the reform. (Fig 3 text labels:) Comparison Chart of Performance Before and After Digital Transformation Grade 23 students Grade 22 students Improvement rate Final exam Classroom performance In class homework (In-class assignments) Operation experiment (Practical experiment) [Chart shows percentage increases from 22nd to 23rd cohort across 4 categories: Final Exam ~20%, Classroom Performance ~40%, In-class Assignments ~20%, Practical Experiments ~-5%? - Note: The graph values are inconsistent with the text description "significant improvement")

Text describing Fig 3 insights: (1) AI + Knowledge Graph significantly enhances student participation and helps them understand relationships between knowledge points and grasp difficult concepts, leading to improvements in classroom performance and in-class assignments. (2) VR Measurement Experiments significantly improve the accuracy of students' operational procedures, helping them correct non-standard actions and cultivate safety awareness, consequently increasing practical experiment scores. (3) The effective integration of these three aspects significantly enhances students' mastery of course knowledge points and deepens their understanding of key topics, ultimately leading to marked improvements in final exam scores.

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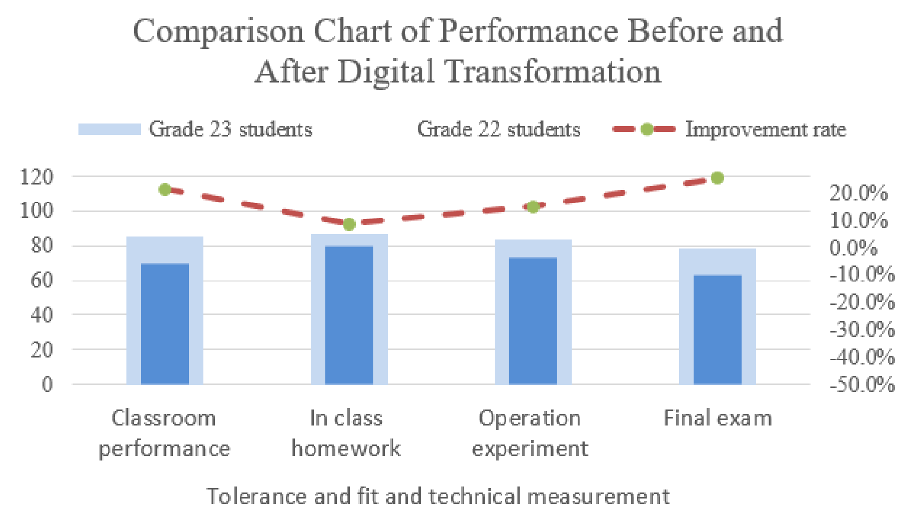

Figure 3. Comparison Chart of Reform Outcomes

2.5. Teaching Team and Industry-Education Platform

The team holds project approval for an MIIT "Specialized, Refined, Advanced, and New" Industrial College (Virtual Simulation Direction) and has established collaborations with companies like Unity and Shanghai Aerospace Intelligent Equipment. They have also published textbooks like Engineering Practice Virtual Simulation. The laboratory is equipped with ¥5 million worth of virtual simulation facilities, supporting the implementation of the "AI + Graph + VR" technological closed-loop to serve talent development and technological advancement in the Yangtze River Delta region.

3. Research Conclusion

Through "AI Assistant + Knowledge Graph + VR Experiments," this course established a smart teaching closed-loop, achieving three major innovative breakthroughs:

(1) Technology Integration: Covering all aspects of "learn-practice-assess": e.g., the IMA platform dynamically reorganizes teaching resources; knowledge graphs overcome knowledge fragmentation; VR experiments replace high-cost physical operations, reducing costs and increasing efficiency.

(2) Ideological Integration: The "craftsmen" case repository transforms technical standards into carriers for moral education. Using regional, professional case studies (e.g., reducer precision design) achieves synchronized teaching of professional knowledge and moral education, addressing the "two separate layers" problem.

(3) Resource Optimization: Through industry-education collaboration (enterprise research projects) and student-teacher co-construction (innovation projects), a sustainable, updatable teaching resource ecosystem was formed. Student awards in engineering competitions and improved grades validate the effectiveness of the reform.

(4) By reshaping traditional engineering pedagogy using digital technology, the course provides a reusable practical path for cultivating digital-savvy craftsmen, aligning with the core demand for education transformation driven by New Quality Productive Forces.

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