Exploration of Application Models of AR Technology in Industry-Education Integration Teaching in Mechanical Engineering: A Case Study of Hebei University of Science and Technology

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Abstract: *As the continuously developing of intelligent manufacturing and industrial upgrade, there are higher demands on the practical ability, job adaptability and engineering literacy of talents trained by the mechanical discipline but currently the teaching in the mechanical discipline is often facing problems such as disconnecting with industry, not integrating real enterprise scenarios well, lack of practical training resources which restricts the improvement of educational effectiveness of industry-education integration. Augmented reality (AR) technology has characteristics like virtual-real integration, real-time interaction, 3D visualization and scenario simulation provides a new way to teach reform in the mechanical discipline. In this paper we review the practical difficulty in current industry-education integration teaching in the mechanical discipline from its present situation, analyse the advantage of AR technology in empowering industry-education integration teaching, propose a school-enterprise dual-teacher teaching mode based on AR technology and then implement it into course teaching at the School of Mechanical Engineering, Hebei University of Science and Technology. Study results indicate that AR technology can greatly improve the intuitiveness of cognition of mechanical structure, standardize learning operation procedure, making the teaching contextual; it can effectively make up for the shortcoming of traditional teaching about insufficient equipment resource, difficult to understand processes, shallow industry-education integration, high safety risk, etc., giving some references for teaching reform in industry-education integration in the mechanical discipline.*

Keywords: *AR technology; mechanical discipline; industry-education integration; teaching model; school-enterprise collaboration*

1. Introduction

With the rapid transformation toward digitalization, networking, and intelligence, the upgrading of the industrial structure puts higher demands on the knowledge structure, technical skills and professional literacy of mechanical talents. Mechanical discipline that serves equipment manufacturing, intelligent manufacturing, and industrial automation teaches both basic theories and cultivates engineering practical ability and job competence as well. With increasing depth of industry-education integration, we should integrate teaching in the mechanical discipline into the actual work processes, job tasks and professional ability standards of enterprises. In general, mechanical courses have complicated structures, abstract principles, rigid operating procedures, and strong dependency on practices. Traditional classroom teaching mainly depends on PPT lectures, blackboard writing, and limited on-campus practical training which makes it hard for students to observe complex mechanical structures and dynamic process flow, and their participation and initiative are relatively low. On the one hand, the on-campus equipment has a long update cycle and limited quantity; on the other hand, the cost of organizing on-site teaching in enterprises is high and there are strict safety management requirements. Students often encounter problems such as "cannot see, cannot enter, cannot do, and cannot practice enough", they can't well meet the talent needs of the high-end equipment manufacturing industry. How to use new technologies to reconstruct the teaching scenario in the mechanical discipline and improve the authenticity and effectiveness of industry-education integration becomes an important topic in current teaching reform.

Emerging technologies such as Virtual Reality (VR), Augmented Reality (AR) that superimposes virtual information onto the real environment providing an interactive experience of virtual-real

integration with high immersion and strong interactivity is a new technology path for engineering teaching innovation, offering new opportunities for innovating education and teaching methods, playing an important enabling and driving role in promoting educational informatization and digitalization[1].

There are some studies applying AR technology into education now. The team led by Cai Su from Beijing Normal University demonstrated that AR technology can greatly promote spatial cognitive ability and mastery of operational skills in the STEM (Science, Technology, Engineering, Mathematics) field[2], combining AR technology with brain-computer interface technology to improve students' attention during the process of scientific inquiry[3]; Zhang Yingying designed a mobile teaching system for engineering graphics based on VR/AR[4]; Li Xiaochun et al. studied and practised AR technology in engineering training teaching[5]; Huang Haiying et al., developed an AR interactive platform for internal combustion engine plunger pumps[6]. Application research of AR technology in the field of engineering education become richer and show great advantages in visual display, scenario simulation and practical training, but lack of discussing about systematic applications. Especially as to how to rely on AR technology to realize school-enterprise collaborative education, no mature application model has yet been produced. Based on analyzing the current situation of industry-education integration teaching in the mechanical discipline, according to the teaching characteristics of the mechanical discipline and practical needs of industry-education integration, we discussed how AR technology empowerment teaching reform, build up an application model of industry-education integration teaching in the mechanical discipline supported by AR technology, achieve virtual-real integration and industry-education integration and analyzed its practical path and implementation effects combined with a specific case of Hebei University of Science and Technology which provide references for classroom teaching reform, practical teaching innovation and school-enterprise collaborative education via industry-education integration in the mechanical discipline.

2. AR Technology Empowering Industry-Education Integration Teaching in the Mechanical Discipline

2.1 Current Status of Industry-Education Integration Teaching in the Mechanical Discipline

In light of the digital and intelligent transformation of the manufacturing industry, the talent cultivation in the mechanical discipline has shifted from imparting knowledge to be able to adapt to jobs and drive innovations; Industry-education integration was one way to improve the quality of talent cultivation. The colleges and universities actively explore co-building practical training bases with enterprises, develop curriculum resources, organize enterprise internships and introduce industry mentors, strengthen the link between teaching in the mechanical discipline and industrial development. But there are still some problems based on the implementation results as follows: First, lack of depth of school-enterprise cooperation. Most of the cooperation only involves signing agreements, short-term internships or special lectures, but the participation of enterprises in formulating course objectives, design course contents and implement teaching activities is low. Secondly, Lack of close links between teaching content and enterprise job requirements. Emphasis too much on the completeness of the theoretical system, not enough incorporate typical job tasks, process specifications and production standards, resulting in poor adaptability of students entering enterprises face complex working conditions and real tasks. Thirdly, Limitation of practical teaching resources. Mechanical courses rely heavily on equipment and venues, however, due to restrictions caused by funding, equipment update and maintenance cost, the on-campus practical training can't timely reflect new technologies, new processes and new standards on the front line of enterprises. Enterprise sites have real environment and advanced equipment, however, due to its production rhythm and safety management, it's hard for them to use for teaching on a long-term and regular basis, which leads to a dual dilemma of "insufficient on-campus resources and difficult-to-use off-campus resources".

In general, despite some progress on industry-education integration teaching in the mechanical discipline, insufficient authenticity of practical scenarios and imperfect school-enterprise collaborative education mechanism limits the improvement of teaching quality, it is an important breakthrough that reconstructing teaching scenarios by means of digital technology and improving the effectiveness of school-enterprise collaborative education for the deepening development of industry-education integration in the mechanical discipline.

2.2 Advantages of AR Technology in Teaching

The characteristics of AR technology that it can superimpose virtual information on a real environment in real time include: virtual-real integration; real-time interaction; three-dimensional visualization; scenario simulation. In comparison with traditional teaching methods, AR can address some issues existing in mechanical discipline teaching including difficult structure cognition, no chance for practice, low authenticity of scenes, relatively high practical operation risk etc., assist mechanical teaching by using AR head-mounted display devices to reproduce three-dimensional models of enterprise industrial-grade equipment at 1:1 scale, overcoming the limitation of space and time for intuitively observing dynamic process flow, thus help to overcome bottlenecks like limited number of on-campus equipment and high risks of actual operation. Meanwhile, AR can also achieve school-enterprise "dual-teacher co-teaching in the same classroom", where enterprise teachers will explain and operate on site, simulating unexpected situation (equipment failure or operational error), but students can remotely enter enterprise sites from school to carry out learning, improving the authenticity and effectiveness of teaching without compromising safety. The main advantages lie in the following three aspects:

2.2.1 AR Technology Can Significantly Enhance the Visual Representation Effect of Mechanical Knowledge

The many knowledge contents of mechanical discipline are very spatial and dynamic (such as the assembly relationship between parts, the motion process of mechanisms, the internal structure of equipment, etc., the dynamic process flow), which is difficult for students to have a general understanding through static pictures or pre-recorded videos under the traditional teaching mode. By using live dynamic demonstration and interaction operating by real people on remote enterprise sites via AR technology, complex mechanical structures become intuitive and dynamic, allowing students to see the equipment structures, understand its working principle, and analyze the assembly logic in real scenarios, greatly reducing the difficulty of learning and increasing cognitive efficiency.

2.2.2 AR Technology Helps Improve the Contextual Authenticity of Industry-Education Integration Teaching

The talent cultivation in mechanical discipline links the teaching process and production process and the relation between course content and job tasks with AR technology to digitize the equipment information, processing standards, operation procedures, and fault cases at enterprise sites and integrate it into classroom teaching. The students are no longer required to go to the enterprise site completely but can use a real job task on campus by using an AR system platform (identify the sequence for assembling equipment, troubleshoot the fault point, simulate maintenance process, understand process parameter) which helps improve the understanding of job processes and occupational standards making classroom learning more practice- and career-oriented.

2.2.3 AR Technology Helps Improve the Continuous Supply Capacity of Teaching Resources

How fast are the updates of equipment in today's era of rapid technological development? Schools do not have enough funds to buy the latest technology equipment each year. There are a lot of real equipment, processes, and engineering cases in enterprises. Resources from enterprise sites with the aid of AR technology can be curriculum resources on campus: job specifications, process details, and actual engineering cases can all be included as part of teaching content, "digitalizing enterprise scenarios into the classroom". The way we develop resources expands our scope for teaching resources and improves the cutting edge, authenticity, and industry adaptability of course content, extending the time and space of practical teaching. For expensive and risky equipment, AR technology takes advantage of its "low cost, low risk", solving the problem that on-campus practical training has limitation of equipment quantity and high operation risks.

In brief terms, AR technology has great teaching advantages for industry-education integration teaching in the mechanical discipline: it improves the degree of visualization of mechanical knowledge and interactivity of classroom teaching; it connects on-campus teaching with enterprise job scenarios, solving the problem of lack of practical teaching resources.

2.3 School-Enterprise Dual-Teacher Teaching Model Based on AR Technology

2.3.1 Role Division of School-Enterprise Dual Teachers

In this paper we established a school-enterprise dual-teacher teaching mode with AR technology.

School-enterprise dual teachers complement each other: On-campus mentor lays down the foundation; building students' solid professional theoretical system, controlling academic norm, guiding frontier thinking of the discipline and ensuring knowledge being systematic and rigorous; Enterprise mentors focus on "real-world practice", bring real workshop production and real project engineering cases from enterprises through AR remote practical operations so as to cultivate students' ability for solving complex frontline problems and professional literacy. Two parties divide work and cooperate to complete students' transition from "knowledge-based accumulation" to "ability-based output".

2.3.2 Construction of a Remote Real-Scene AR Live Broadcast Teaching System

The AR live broadcast teaching system designed in our paper uses B/S (Browser/Server) architecture without complicated terminal installations. It allows teachers and students to access it using browser on PC, tablet or AR glasses, which simplifies the difficulty of adapting terminals as well as helps update iteration and operation and maintenance management. The architecture of our system consists of five layers from bottom to top: the bottom layer is called base layer (digital infrastructure layer), the middle layers are service support layer, scenario application layer, resource integration layer; the upper layer is called guarantee layer (security operations layer). Meanwhile, we have local deployment capability. All core teaching data like course materials, student grades, recorded videos etc. will be stored locally on server, effectively reduce the risk of data leakage and ensure data security. We have equipped with local automated backup tools that supports daily incremental backup and full backup, ensuring data integrity and reliability.

Based on AR technology, integrating hardware device, software function and system architecture, we design an innovative cross-platform, highly interactive teaching solution breaking the spatial constraint in traditional teaching and create a new school-enterprise dual-teacher teaching mode with characteristics of "integration of virtual and real, industry-education integration, and remote collaboration". Establish a trinity interactive space of "school classroom + virtual classroom + enterprise workshop (or laboratory)", realize cross-platform real-time linkage between PC, tablet and AR glasses; using a virtual drawing board, teachers can write formulas, draw graphics, show PPT etc., through collaborative annotation synchronizes content across multiple terminals. It has screen recording function: take real-time screenshot of and annotate live images/virtual models/teaching courseware, and support recording first-person perspective footage from enterprise teachers' AR glasses like experimental operations or equipment disassembly process which are automatically uploaded to the server for storing so that students can easily replay and review them after class. Also supporting screen sharing, teaching material transmission, real-time text and voice communication, ensure smooth interaction during remote teaching, improve the immersion, collaboration and effectiveness of teaching by providing multi-dimensional interactive tools.

3. Exploration of the Application of AR Technology in Industry-Education Integration Teaching in the Mechanical Discipline

In order to verify the effectiveness of our proposed school-enterprise dual-teacher teaching model with AR technology in this paper, we have conducted practical applications on the School of Mechanical Engineering at Hebei University of Science and Technology. Our main practices are as follows:

3.1 Establishing a School-Enterprise Dual-Teacher Collaborative Education Mechanism

Engineers and technical personnel who have rich practical experience in industry enterprises are appointed as off-campus instructors by School. The off-campus instructor must be competent in providing real engineering cases and giving on-site practical guidance. After their individual application, review by school and appointment by school, they will get formal appointment certificate from the school. We also need to stress the role of school teachers as "gatekeeper" for theoretical guidance and academic norms. In the collaborative education mechanism, the role of school teachers cannot restrict themselves only to classroom teaching and thesis supervision anymore but should actively act as a bridge and converter between academia and industry. They need to deeply understand the technical needs of enterprises; connect with real engineering cases given by enterprise mentors and convert them into pedagogical form and academic form. Establishing a regular communication mechanism between school and enterprise dual teachers and joint development of professional training programs, course syllabi, etc., so that deep industry-education integration can be achieved.

3.2 Developing a Virtual Disassembly and Assembly and Digital Twin System for Industrial Additive Manufacturing Equipment

For instance, usually there is only small desktop machines on the teaching equipment in the school if you took this course "Additive Manufacturing Equipment", but most of the equipment used in enterprises is industrial machines which have big sizes and high prices (especially multi-laser additive manufacturing equipment can cost millions or tens of millions), the schools are restricted by funds that they cannot buy several industrial grade machines let alone all students actually disassembling and assembling it by hand. So we together with an enterprise from Hebei University of Science and Technology designed a virtual disassembly and assembly system for stereolithography additive manufacturing equipment using point-based authorization so that the whole class could study and take assessments online at once. It has two modes; one is learning mode and another is assessment mode. Main functions include: equipment disassembly, assembly and printing.

3.3 Developing an AR Live Broadcast Teaching Platform to Realize School-Enterprise Dual-Teacher Co-Teaching in the Same Classroom

Hebei University of Science and Technology with an enterprise to develop a "Remote Real-Scene AR Live Broadcast Teaching System", to realize school-enterprise "dual-teacher co-teaching in the same classroom". For example, the course "Additive Manufacturing Equipment": Laser Powder Bed Fusion (LPBF), which is one of the key contents in metal 3D printing due to its use of micron-sized metal powder, has very high safety requirements. There are hazards if not protected well, such as inhaling dust and explosion risk. Operators must wear protective clothing, such as anti-static clothes, gloves and goggles. In addition, the operation process of LPBF equipment is complicated so that operators should be trained and assessed systematically before practicing on the machine. Main process:

a. Data processing. Convert the model into STL format, repair, add supports, setting parameters, slicing, layering;

b. Prepare equipment and materials. Level substrate, adjust scraper, loading metal powder, connecting and filling protective gas;

c. Printing and post-processing. Import the printing file to print, taking out the parts from the printer, removing the support, doing heat treatment or surface treatment on the formed parts.

Considering that the complicated and extremely dangerous operating process of metal 3D printing equipment, we use the "Remote Real-Scene AR Live Broadcast Teaching System" in this part of teaching to realize school-enterprise "dual-teacher co-teaching in the same classroom": on-campus teachers monitor the operating status of each terminal in real-time to guarantee the smooth progress of remote teaching; enterprise teachers wear an AR head-mounted display device, connect the printing site with the system in real time using the virtual-real integration technology to mark some important teaching content (such as the structure and working principle of the powder feeding mechanism and the composition of the laser optical path). Students can synchronize the first-person perspective footage of enterprise teachers via the AR live broadcast system to intuitively view the production site and equipment operation process. The enterprise teacher will also synchronously explain the key steps and precautions during practical operations so that students can ask questions in real time by flash comment, voice or text. All the teaching processes are automatically recorded and stored into the database for convenient playback and review after class. It overcomes the limitation of the physical location of the traditional classroom, creating a trinity AR learning space: "school classroom—virtual classroom—enterprise site", which links on-campus and off-campus, in-class and out-of-class resources. Virtualize dangerous operations and visualize process parameters, solving the problems of insufficient safety, weak visualization and limited resources in traditional metal 3D printing teaching well, with remarkable teaching effects.

4. Conclusion

In this paper we solve prominent problems existing in the teaching of the mechanical discipline by adopting a school-enterprise "dual-teacher teaching" model based on AR technology. The construction of a remote real-scene AR live broadcast teaching system realizes virtual-real integrated interaction and remote collaborative teaching that compensate for the deficiency of traditional teaching (lack of sufficient equipment resources), Difficulty in understanding processes; Shallow industry-education

integration and relatively high safety risk. It not only improves the practical operation ability of students and deepen their understanding of complex process principle, but also under the real-time remote guidance from enterprise mentors, synchronize the update of teaching content with the development of industry technology. In this paper, taking the School of Mechanical Engineering at Hebei University of Science and Technology as an example, shows how AR technology is applied to industry-education integration teaching within the mechanical discipline, provides a solution with a certain level of promotion for the field of engineering education. Technical framework and teaching methods apply to other high-cost, high-risk engineering technology teaching and training scenes, promote innovation of engineering education models.

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