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Research on the Application of CDIO in Teaching of Practical Courses

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Abstract:

In response to the scientific and technological demands arising from the rapid development of the country and in alignment with the national strategy of "Made in China 2025", we are actively exploring the construction of practical courses. Considering the current teaching situation of 3D printing courses and integrating the CDIO engineering education concept, we propose a novel teaching mode and evaluation method. This approach aims to cultivate students' practical application abilities and enhance the overall teaching quality.

Keywords:

CDIO
Project-driven
3D printing
Course reform

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1. Introduction

In recent years, the CDIO engineering education model has achieved significant results in the international education sector and has been vigorously promoted and developed in practical course teaching in major universities in China. The CDIO concept includes four parts: Conceive, Design, Implement, and Operate. It emphasizes "learning by doing" and "project-based learning", establishes a new concept of "student-centeredness", and inspires students to take the initiative in learning. Under the guidance of the CDIO education philosophy, the teaching content is progressive and unfolds layer by layer. In classroom teaching, a dual mode combining flipped classrooms and online teaching is adopted; in practical operations, practical training projects are the main focus, emphasizing students' independent hands-on practice; in simulation operations, group cooperation is the main focus to enhance collaboration and engineering system capabilities [1].

To address new economic challenges, serve the rapidly developing technological needs of the country, and respond to the national strategy of "Made in China 2025", universities have formed a new engineering concept in talent cultivation. Schools are vigorously developing practical course construction, striving to cultivate more applied technical talents for society. Among them, 3D printing, as a new rapid prototyping technology, has completely subverted the traditional manufacturing industry's concept and model of material reduction manufacturing, becoming a practical topic of focus for countries worldwide. Major universities in China have opened relevant courses, gradually popularizing them from universities to middle schools. Currently, there is a huge shortage of talent in China's manufacturing industry, and 3D printing application talents are in short supply. These applied talents mainly come from major universities and are the builders and successors of future society [2]. Therefore, strengthening the construction of 3D printing courses is one of the important measures for China to become a world scientific and technological power.

2. Current situation of 3D printing course teaching

China's 3D printing education started relatively late, and its popularity remains in individual developed regions. There is still a gap in international competitiveness, risk resistance, and technological innovation compared to developed countries [3]. There are also some problems in transforming theoretical research into practical applications.

2.1. Teaching Aspects

Currently, although some higher education institutions and vocational schools have begun to attach importance to 3D printing, most of them are affiliated with machinery-related majors and do not have complete curriculum system guidance. The main teaching content focuses on the use of 3D modeling software and mechanical mold manufacturing. The teaching format is single, not deep enough, and lacks the inherent motivation for innovative transformation.

2.2. Evaluation aspects

The evaluation model still adopts a combination of traditional classroom attendance scores and written test scores, ignoring the innovative and practical characteristics of 3D printing teaching. It only focuses on the results and ignores the process, resulting in inadequate evaluation of students' comprehensive abilities such as innovation, practical skills, and teamwork demonstrated during the learning process. Teachers cannot truly grasp students' learning situations based on the evaluation, affecting the teaching effectiveness to some extent.

3. 3D printing teaching design based on the CDIO concept

According to the current problems in 3D printing teaching, combined with the CDIO engineering education concept, the course should integrate classroom teaching with project-based teaching, implementing the "student-centered" teaching philosophy and allowing students to experience the joy of "learning by doing."

Based on the learning trajectory of the 3D printing course, the entire course is divided into three stages: 3D software learning, 3D project engineering training, and university student 3D maker space operation. The first stage focuses on learning 3D max software operations, with teaching projects such as "school sandbox model design", "graduation cultural gift design", and "fighting viruses, 3D printed mask adjuster design." This stage requires students to master basic software operations and design structurally sound and creative 3D models, reflecting the conception (C) and design (D) aspects of the CDIO concept.

The second stage is completed in the university's engineering training center, using 3D printers and various machining tools to complete the printing practice of the first-stage models. Students are required to understand the working principles of 3D printers, master polymer molding processes, and be familiar with secondary processing and assembly of parts. This stage embodies the implementation (I) aspect of the CDIO concept.

In the third stage, with the support of the school and teachers, a university student 3D maker space is established. Industry experts are invited to regularly hold training seminars on new technologies in the industry, encouraging students to actively participate in relevant competitions at home and abroad, explore commercialization models of 3D printing, contact external enterprises for simulated entrepreneurship, and tap into the commercial value of 3D printing. This stage represents the operation (O) aspect of the CDIO concept.

The entire course is project-based, with corresponding project examples at each stage. Students complete projects in groups and present their achievements at the end of each stage, forming a comprehensive evaluation. The course design is progressive and layered, moving from theoretical knowledge to practical operations and then to integrated projects, guiding students to learn through practice and transform knowledge through hands-on experience.

4. Implementation of 3D printing teaching based on the CDIO concept

Combining the CDIO concept with the characteristics of 3D printing courses, we adopt corresponding teaching methods according to the course content during the teaching implementation process, integrating various teaching methods to achieve the best teaching effect.

4.1. Implementation of teaching methods

4.1.1. Flipped classroom

In the 3D max software learning stage, teaching platforms such as "Rain Classroom" are utilized to facilitate students' online self-study, problem discovery, and classroom problem-solving as the main learning mode. Teachers prepare teaching resources as micro-lecture videos before class and distribute them to students for self-study. During class, teachers and students discuss key and difficult points, and the teacher summarizes the students' self-study achievements. After class, students explore independently and consult relevant supplementary materials to broaden their horizons. The classroom is student-centered, stimulating students' interest in active learning.

4.1.2. Project-driven

During the 3D printing engineering training stage, students are divided into groups and actively learn with tasks. The teacher guides students to "learn by doing," discovering and solving problems in a timely manner. After the training, each group presents their achievements to the whole class, and the groups evaluate each other based on the presentation. This teaching method not only enhances students' hands-on practical ability but also fosters their teamwork spirit.

4.1.3. Simulated operation

The college makerspace is a comprehensive platform that relies on high-quality resources from the university, with college students as the main participants, specifically providing entrepreneurship services for college students. It is an important platform for college students' innovation and entrepreneurship activities. Students with a common interest in 3D printing technology can gather, socialize, and collaborate here. During their free time, students can independently operate, hold industry lectures, participate in professional competitions, and even form benign business partnerships with enterprises under the guidance of teachers, laying a solid foundation for future work and contributing to the development of 3D printing technology in China.

4.2. Assessment and evaluation system

The CDIO education concept emphasizes the cultivation of students' comprehensive abilities. Based on course design, students should be evaluated from multiple perspectives.

Software learning stage: Software belongs to basic knowledge, and students' learning status can be judged through pre-class learning task sheets and staged computer tests. Teachers should constantly monitor students' knowledge mastery during class communication and Q&A sessions, focusing on explaining key and difficult points.

Engineering training stage: Engineering training is conducted in groups, and the final results are presented and reported to the whole class. During the presentation, anonymous scoring is used for a comprehensive evaluation, with specific evaluation criteria as shown in **Table 1**.

The quantitative evaluation criteria are calculated based on a percentage system, including the ability to complete micro-lecture learning tasks and practice independently (5%), actively discover and raise questions during self-study (10%), think creatively, design, and practice during course implementation (10%), collaborate with classmates and distribute work among group members (15%), achieve a high level of completion, reasonable structure, and functional perfection in their work, demonstrating practicality and relevance (30%), and deliver a smooth, logically clear presentation with self-reflection and evaluation (30%).

Simulated operation stage: The makerspace is a

Table 1. Group evaluation scale

Stage	Scoring content		Proportion	Rating
Micro-course learning	Able to complete learning tasks diligently and practice independently		5%	
	Able to actively think, discover problems, and propose own ideas		10%	
Course practice	Able to think independently, design, and engage in hands-on practice		10%	
	Able to unite with classmates and collaborate with team members through a clear division of labor and mutual learning		15%	
	Completion degree of works	The design plan demonstrates creativity, unique methodologies, or innovative use of tools and materials	10%	
		The work exhibits a reasonable structure, stability, durability, safety, harmlessness, and an exquisite and aesthetically pleasing exterior design	10%	
		The functionality is comprehensive, possessing a certain degree of practicality and practical significance	10%	
Summary and reflection	The presentation demonstrates graceful and appropriate behavior, fluent language expression, clear logic, vigorous spirit, and youthful vitality		20%	
	Able to self-reflect and evaluate their own performance during the entire activity		10%	

simulated community independently operated by students with support from the school and teachers, offering a relatively high degree of freedom. The makerspace focuses on the learning process, with students as the main subjects, cultivating their ability to learn and develop independently. A comprehensive evaluation can be conducted based on students' innovative designs, competition achievements, patent outcomes, and revenue status of simulated entrepreneurship. Due to the complexity of space activities and frequent personnel changes, teachers should constantly monitor students' operational situation to prevent adverse events.

Combining process evaluation with result evaluation, and with students as the evaluation subjects, the above three aspects form a multi-dimensional evaluation mechanism.

5. Conclusion

Under the guidance of the CDIO engineering education concept, this paper reconstructs the teaching content of the practical course "3D Printing" and establishes a multi-dimensional evaluation criterion, addressing issues in traditional 3D printing teaching and enhancing students' engineering quality. However, many challenges still exist in practical teaching. Continuous efforts should be made to improve teaching quality and cultivate high-end talents that meet national and societal expectations.

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Disclosure statement

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