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Construction and Improvement of the Computer-Aided Design Technology Course for Mechanical Design, Manufacturing, and Automation under the Framework of "Emerging Engineering Education"

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Abstract: Since Ministry of Education of the People's Republic of China introduced the concept of "Emerging Engineering Education" (also known as "New Engineering Education") in 2017, the traditional curriculum of Mechanical Design, Manufacturing, and Automation has revealed numerous shortages: incomprehensive assessment indicators, focusing on theoretical reaching and students' lack of exposure to practical engineering problems. The elective course "Computer-Aided Design Technology" can address these deficiencies to some extent. This paper begins with the theory of "Emerging Engineering Education", explores how the course "Computer Aided Design Technology" compensates for the inadequacies of traditional professional courses, and proposes improvements to the curriculum to meet the demands for mechanical engineering professionals under the background of "Emerging Engineering Education".

1. Introduction

The new round of science and technological revolution and industrial transformation has imposed higher and more comprehensive requirements on the quality and competences of engineering technicians. As a crucial element of higher education system, higher engineering education plays an indispensable role in scientific and technological progress and industrial upgrading. To deepen the reform of engineering education, and accelerate the construction of a strong engineering education system, Ministry of Education of the People's Republic of China pushed forward the construction and development of "Emerging Engineering Education" in February 2017, aiming to help to build the higher education system and enhance competitiveness in the global technology industry.[1]

According with the requirement for the educational philosophy of "Emerging Engineering Education" , the major Mechanical Design, Manufacturing and Automation prioritizes cultivating interdisciplinary engineering talents equipped with the ability to solve complex engineering problems, proficiently utilize modern engineering tools, demonstrate practical competencies, and possess a global vision [2], as illustrated in Fig. 1.

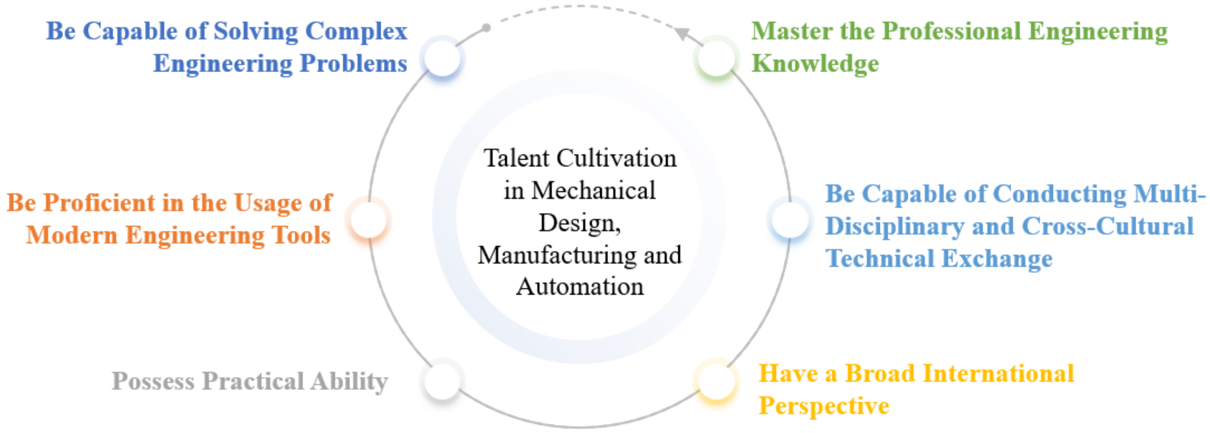

Figure 1 Talent cultivation in Mechanical Design, Manufacturing and Automation

As one of the elective courses of Mechanical Design, Manufacturing and Automation, Computer-Aided Design Technology plays a vital role in complementing core traditional courses such as Mechanical Design. Within the framework of developing advanced mechanical engineering professionals, this course establishes a sound foundation for students engaged in design, manufacturing, research, and development in the field of mechanical. It cultivates mechanical students in applying specialized software and theoretical knowledge to address engineering challenges, so as to meet the demands of "Emerging Engineering Education" for mechanical engineering talents.

This paper proposes the content of the Computer-Aided Design Technology and reform measures for the Computer-Aided Design Technology course, within the context of "Emerging Engineering Education". These measures include restructuring course objectives and optimizing teaching content, with the ultimate goal of enabling students to master various CAD tools and enhance their problem-solving capabilities in practical engineering scenarios, fulfilling the requirements of "Emerging Engineering Education" for mechanical engineering professionals.

2. Course Content and Assessment Methods

2.1. Course Content and Teaching Objectives

The computer-aided design courses of most schools mainly focus on a single CAD software, aiming to enable students to master basic two-dimensional or three-dimensional modelling techniques. This Computer-Aided Design Technology course deeply integrates mechanical engineering professional knowledge with modern advanced computer technology, laying a necessary foundation for students to engage in mechanical design, manufacturing, research and development. It focuses on two core modules: numerical calculation methods and their applications in the mechanical field, and computer-aided process planning and computer-aided manufacturing technology based on CAD. This course aims to cultivate students' ability to use computer programming software for data analysis, engineering modelling and analysis, and optimization Design, as well as to use mechanical CAD software for process planning and CAM programming in mechanical manufacturing processes. The specific content of course is shown in Fig. 2. Through the organic integration of these two modules, it is expected that students are able to use computer-aided technology for engineering data analysis and optimization, and use CAD software for mechanical product design and development, so that the students' comprehensive practical ability can be cultivated. It is hoped that students can adapt to the development of modern mechanical engineering technology and develop the habit of lifelong learning. The cultivation of these abilities will lay a solid foundation for students' future work in mechanical design, manufacturing process planning, product development, enabling them to better adapt to the digital and intelligent development trend of modern manufacturing under the framework of "Emerging Engineering Education".

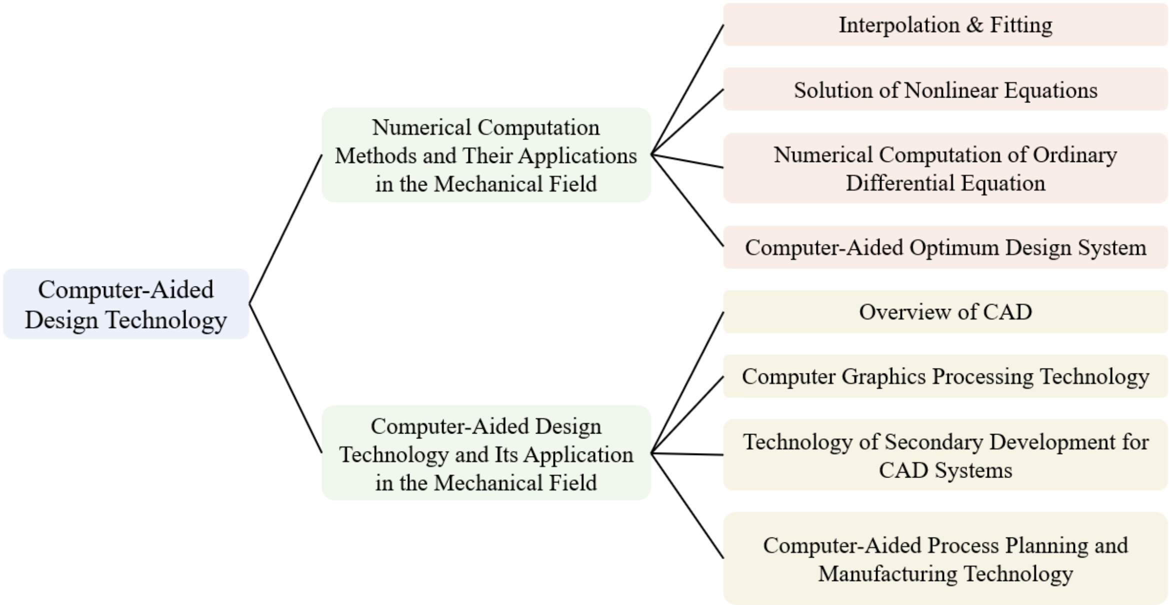

Figure 2: The Content of Computer-Aided Design Technology

2.2. Diversified Assessment Methods

The previous undergraduate course assessment methods were primarily based on final written examinations. Although easy and simple to handle, they had many shortcomings, such as students focusing more on memorization rather than understanding and studying merely for exams. This kind of assessment method neglected the learning process and failed to enable students to proficiently apply professional knowledge, making it difficult to meet the "Emerging Engineering Education" emphasis on cultivating high-level, high-standard, and high-tier new interdisciplinary applied engineering talents [3].

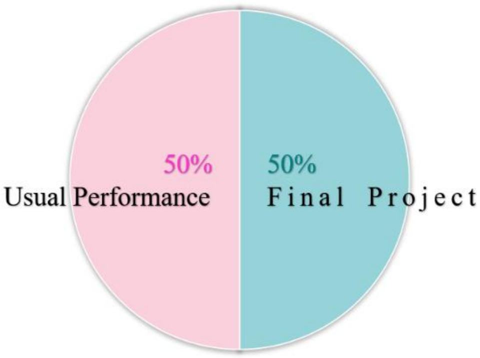

Figure 3: The Composition of Student’s Total Score of Computer-Aided Design Technology

At present, Computer-aided design technology is based on the requirements of “Emerging Engineering Education”, committed to cultivating interdisciplinary engineering innovation talents. It breaks through the traditional single final exam assessment system of engineering education and establishes a diversified and process-oriented assessment method characterized by continuity, multi-dimensionality, and emphasis on practice. At the same time, it comprehensively examines students' classroom performance, degree of knowledge mastery, practical abilities, and innovative thinking methods through diversified tasks. The students' total score consists of two major components: usual performance (accounting for 50%) and a final project (accounting for 50%), as shown in Fig. 3.

The usual performance assessment includes six evaluation dimensions, providing a comprehensive and objective assessment of students' process-oriented learning across online and offline, in-class and after-class, basic knowledge, and extended knowledge: class participation (10%), online learning engagement (5%), computer lab performance (15%), homework assignments (15%), unit knowledge tests (20%), and making thematic review demonstrate documents (35%), as is revealed in fig. 4.

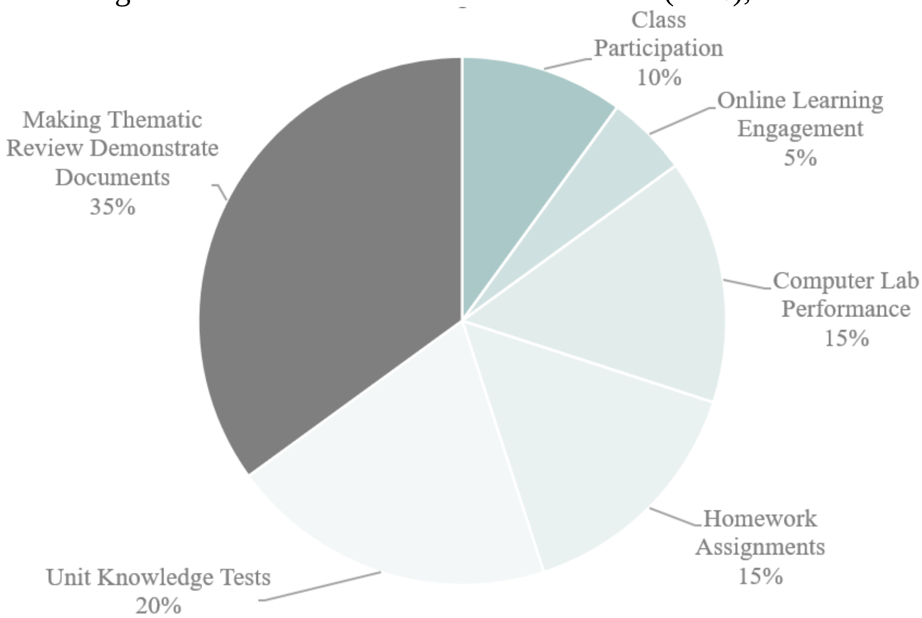

Figure 4: The Proportion of the Composition of Usual Performance Assessment

Class participation is accurately recorded using an intelligent software management system to authentically track students' attendance. Online learning is primarily based on the release of discussion topics related to the course on an online platform (example discussion topic: Please discuss how to evaluate the quality of numerical algorithms.), comprehensively recording students' discussion participation frequency, novelty of viewpoints, logical argumentation, and other indicators to form a multidimensional evaluation result. During the semester (totalling 36 class hours), students have three opportunities (6 class hours) to attend computer lab sessions at the school's computer room. Through these sessions, teachers can observe and assess students' actual software usage in time, such as operational proficiency and problem-solving abilities, while providing professional guidance on students' computer lab assignments. Five homework are assigned for the five main knowledge modules of the course, emphasizing the integration of theory and practice, and assessing both foundational knowledge mastery and problem-solving skills. After each teaching unit, unit knowledge tests are conducted through online platform. The online software pays attention to assessing foundational knowledge, utilizing diverse question types such as single-choice, multiple-choice, fill-in-the-blank, and true or false questions to comprehensively evaluate students' study achievement. Students independently search for relevant literature to make a thematic review demonstrate document. By choosing topics closely related to modern mechanical design development, such as "innovative design," "virtual design," or "bionic design," students make review demonstrate document covering technical introductions, technological developments, and application cases, so as to exercise their abilities in literature research and knowledge integration. Through this task, students will not only gain a systematic and comprehensive understanding of the relevant technological developments, but also enhance their abilities in literature retrieval, analysis, and summarization.

The final grade is based on professional knowledge and course content, requiring students to independently select topics and complete five small projects on professional knowledge of mechanical engineering and computer-aided design technology: literature review, independent topic selection, computer programming, technical documentation writing, and project presentation and defence. This assessment task places emphasis on evaluating students' comprehension and mastery of the techniques learned in class. Students address relevant engineering problems under five themes: computer processing of engineering data, analysis and solution of engineering problems, computer-aided optimization design, computer-aided process design, and CAD system secondary development, completing tasks such as programming and calculations. Through this task, students can consolidate knowledge learned in class by handling practical engineering problems and enhance their technical application abilities and problem-solving skills for complex engineering challenges.

The following will use the specific content of the engineering problem analysis and solution module in the project report and the standard for evaluation.

Specific subject: Engineering Problem Analysis and Solution:

(1)Analyse an engineering problem and provide the corresponding mathematical model (differential equation or nonlinear equation);

(2)Solve this equation through programming;

(3)Present the solution results.

An example of a student's solution is as follows:

(1)Analyse an engineering problem and provide the corresponding mathematical model (differential equation or nonlinear equation):

The engineering problem: The fig. 5 below shows a guide rod mechanism driving the pivot point O of a simple pendulum to perform horizontal motion according to the known law $x = r \cdot sin\omega t$. Determine the differential equation of motion for the mass particle m, given that the pendulum length $l = 10\ cm$, the connecting rod length $r = 5\ cm$, the angular velocity of the connecting rod $\omega = \pi/4\ rad/s$, and the initial position of the pendulum is vertical ($\theta = 0$). (Source: Mechanical Dynamics Homework)

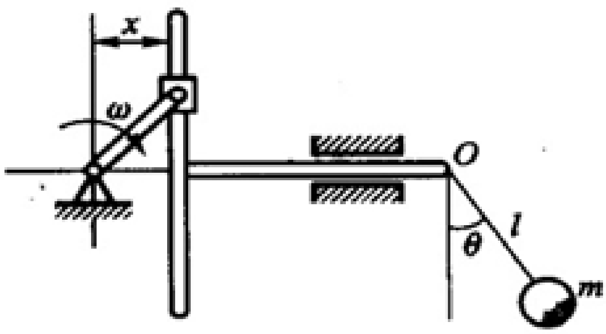

Figure 5: The Illustrating Picture

List the kinetic equation:

$$L = T - V = \frac{1}{2}ml^2\dot{\theta}^2 + \frac{1}{2}mr^2\omega^2\cos^2\omega t + mrl\omega\dot{\theta}\cos\omega t\cos\theta + mgl\cos\theta$$

$$\frac{\partial L}{\partial\dot{\theta}} = ml^2\dot{\theta} + mrl\omega\cos\omega t\cos\theta \qquad \frac{\partial L}{\partial\theta} = -mrl\omega\cos\omega t\sin\theta - mgl\sin\theta$$

$$From\ \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \theta} = 0$$

$$ml^2\ddot{\theta} - mrl\omega\left(\omega \sin \omega t \cos \theta + \dot{\theta} \cos \omega t \sin \theta\right) + mrl\omega \cos \omega t \sin \theta + mgl \sin \theta = 0$$

$$\text{Then:}\quad \ddot{\theta} - \frac{r}{l}\omega^2 \sin \omega t \cos \theta + \frac{g}{l} \sin \theta = 0$$

(2)Solve this equation through programming. The program is shown in fig. 6 as follow.

```
hh3.m
xspan = [0 30];
l=10;%l:Pendulum Length
%y0: Initial Angle
r=5;%Connecting Rod Length
w=pi/4;%The Angular Velocity of the Connecting Rod
g=9.8; % Gravitational Acceleration
y0=0;
odefun = @ (x,y) (r./l.*w.*w.*sin(w.*x).*cos(y)-g./l.*sin(y));
[x,y]=ode45(odefun,xspan,y0);
plot(x,y,'*-k')
title('THE ANGLES OF PENDULUMS AT EACH TIME')
xlabel('TIME t/s')
ylabel('THE ANGLE OF THE SIMPLE PENDULUM')
```

Figure 6: MATLAB Program

(3)Present the solution results. The output graph line is illustrated in the fig. 7.

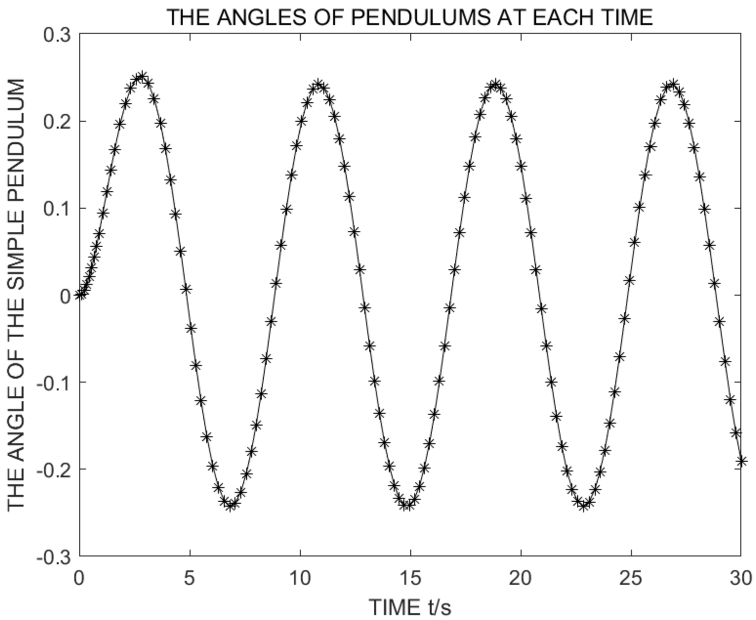

Figure 7: Program Execution Result

This student first identified an appropriate engineering problem based on the given requirements and formulates the differential equation for the mass point M. Then the student wrote a MATLAB program to solve the equation and presents the computational results. This student successfully selected a suitable engineering problem from professional course homework, established the fundamental conditions for the program using kinetic equations, and modified the demonstration program presented in class, ultimately producing a simulation result. With clear explanations and correct programming implementation, this module deserves an excellent grade.

This diversified assessment approach fully embodies the characteristics of "Emerging Engineering Education." It not only comprehensively evaluates students' engineering literacy and innovative capabilities, but also effectively promotes interdisciplinary integration while cultivating independent thinking and problem-solving skills. This provides strong support for developing new engineering talents that meet future industrial demands.

3. The Improvement of Computer-Aided Design Technology under the Framework of "Emerging Engineering Education"

3.1. Integrate cutting-edge technological knowledge and keep pace with the times

The proposal of the "Emerging Engineering Education" concept is a positive response to major national strategies such as "Belt and Road Initiative", "Made in China 2025", and "Internet Plus", aiming to cultivate innovative engineering talents who can adapt to the development of new technologies, new business models, new modes, and new industries [1, 4]. In this era, the "Computer-Aided Design Technology" course should closely align with the development trends of intelligent manufacturing, focusing on introducing emerging cutting-edge technology modules such as additive manufacturing design, virtual reality (VR)/augmented reality (AR) assisted design, and digital twin technology. This will allow students to gain early exposure to relevant technical content, cultivate interdisciplinary thinking and innovation capabilities, lay a solid foundation for future talent development in emerging fields, and support the nation's major strategies.

The following words will take additive manufacturing and virtual reality (VR)/augmented reality (AR) assisted design as examples to explain how to introduce relevant content and the expected goals to be achieved. In terms of additive manufacturing, this course will systematically explain 3D printing design rules, such as support structure design, integrated consideration of materials and structures, and layer slicing [3]. Through project practice and real cross-disciplinary application cases, students will master the methods of additive manufacturing and broaden their interdisciplinary perspectives. In the context of globalization, VR/AR-assisted design technology helps engineers to design together remotely and collaboratively, which will be a major future trend. By introducing VR/AR technology into Computer-Aided Design Technology, students can conduct immersive design in virtual environments and interact with team members in real-time to modify design solutions. The introduction of this technology helps students experience new technologies as well as gaining early understanding of collaborative design approaches.

3.2. The comprehensive application of computer-aided design software enhances the organic connection among various software

At the current stage, the teaching modules of Computer-Aided Design Technology are relatively disconnected, with each module often presented in isolation, lacking systematicity and integrity. Therefore, it is difficult for students to develop comprehensive application of auxiliary technologies and interdisciplinary thinking skills. To meet the demand for innovative engineering talents under the "Emerging Engineering Education" framework, this course aims to break the boundaries of auxiliary design technologies in the future. It will organically integrate seemingly independent knowledge modules such as MATLAB's numerical computation and simulation applications in mechanical engineering, parametric design in CAD systems, and process decision-making in CAPP systems. Simultaneously, it will abandon isolated knowledge point explanations and instead rely on practical projects like aero-engine design and new energy vehicle design to connect the application of multidisciplinary knowledge—including mechanical design, material mechanics, mechanical dynamics, and mechatronic system design—in computer-aided design technology. This approach will establish a teaching system that combines multiple disciplines and integrates theory with practice, guiding students to develop multidisciplinary and multi-technology associative thinking methods. It will enable students to experience the complete design process, deeply understand the entire product development cycle from scratch, and enhance their ability to solve practical problems.

3.3. Cooperate with relevant enterprises to bridge the gap between students and professional workplaces

In response to the new talent cultivation model proposed by "Emerging Engineering Education", and based on summarizing the reform experiences of engineering education talent cultivation models such as the Outstanding Engineers Education Training Program and CDIO, Computer-Aided Design Technology aims to strengthen the cooperation between university and enterprise. By introducing real mechanical product design and manufacturing cases from enterprises into classroom teaching, and inviting experienced enterprise engineers as guest speakers or part-time instructors, students can genuinely understand the design work, standards, and techniques of leading industry enterprises. By learning in a practical, real-world atmosphere, students can consolidate their knowledge, enhance their skill application capabilities and bridge the gap between academia and industry. Through cooperating with relevant enterprises, engineering teaching quality can be improved, for it helps to increase graduates' employability competitiveness, ensure the alignment between talent cultivation quality and industrial development needs, and provide talent support for promoting innovation and development in the mechanical engineering field.

4. Conclusions

Through the above curriculum construction and educational reforms, Computer-Aided Design Technology for mechanical engineering majors will better adapt to the development requirements of "Emerging Engineering Education", and closely align with the talent cultivation requirements of “New Engineering Education”. Hopefully, computer-Aided Design Technology can be better dedicated to cultivating interdisciplinary engineering talents with international perspectives, consciousness of innovation, and practical abilities, thereby training high-quality innovative design talents for the mechanical industry.

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