Computer-Aided Education for Engineering Graphics Courses Using 3D Printing Technology

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Abstract: The modernization and informatization of education have always been important means to improve the quality of education and meet the requirements of social development and construction in China's higher engineering education. Based on the premise of the application of modern advanced manufacturing technology 3D printing and the theoretical method of "digital learning", this paper discusses the deep integration of educational information technology and engineering graphics education and the impact of 3D printing technology on the teaching of product design and engineering graphics courses. Carry out reform research and innovative practice in the teaching content, teaching mode, teaching method, and practice links of engineering graphics courses, establish a set of engineering graphics education systems that meets the requirements of educational informatization, industrial informatization, and intelligence, and carry out teaching practice. Through the comparison and analysis of the implementation effect of teaching practice, the teaching effect is verified, and the research has achieved the purpose of improving the teaching quality and adapting to the quality requirements of advanced mechanical engineering talents in the new era.

1 INTRODUCTION

At present, a new round of world science, technology, and industrial revolution is emerging. It has had a great impact on human society. It will cause profound adjustments to the world economic and political pattern in the future, reshape the global position of national competitiveness, subvert the form, division of labor, and organizational mode of many existing industries, and achieve multi-field integration. Reconstruct people's lives, learning, and way of thinking, and even change the relationship between people and the world. The development of each emerging technology will certainly have a significant impact on the deepening reform of education (Yao Zhiming, 2018; He Kekang, 2019), and the application of each technology as an educational technology will have an impact on the learning environment, teaching methods, experimental means, the design of teaching activities, learning evaluation, etc., thus causing the concept of knowledge production and the mode of knowledge production. And changes in the cognitive patterns and behavior patterns of educators, learners, participants, and other roles. Therefore, it is of great significance to vigorously advocate and deeply study the application of emerging information technology in education and teaching, and carry out computer-aided education.

Engineering science and technology change the world, and engineering education leads to innovation. Since modern times, engineering science and technology have directly linked scientific discoveries with industrial development and become the main driving force of economic and social development. Worldwide, engineering education is the fastest and most far-reaching educational reform. The world is changing, and education must change, which requires new forms of education to cultivate the capabilities and talents needed for today's and future societies and economies (Wang Lina, Chen Lin, 2018; Wu Yan, 2018).

Engineering graphics is an important technical course for higher engineering college students. It cultivates students' fundamental engineering literacy

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and design description and expression of engineering objects and achieves the exchange of information about product design and manufacturing. As a new technology, 3D printing technology is known as a new industrial revolution in the manufacturing industry, which will have a very revolutionary impact on the manufacturing industry. Well, for the theoretical and practical research on the deep integration of the teaching of specific disciplines of emerging information technology and engineering graphics, the establishment of a computer-aided education model is a very novel and important issue. Based on this consideration, in 2018, we received funding from the key research project on the application and development of education informatization of the Sichuan Provincial Department of Education to carry out the above research.

2 3D PRINTING TECHNOLOGY AND CHARACTERISTICS

3D printing technology, also known as additive manufacturing technology, is a technology based on the 3D model of objects, using discrete materials (liquids, powders, etc.) to manufacture complex shapes by layer-by-layer cumulative methods (Li Maoguo, 2016). In recent years, 3D printing technology has developed rapidly and has been widely used. Due to the novel way, it generates products, some products that could not be manufactured by previous processing methods can be produced, expanding the product manufacturing scope. It is widely used in industrial product manufacturing, biomedicine, architectural decoration, cultural and artistic creativity, and other fields (Zhao Ji, Xie Yinbo, 2017).

As a new product production method, the emergence and application of 3D printing technology will have a significant impact on the theory and methods of industrial product design and manufacturing, as shown in the following aspects:

1. 3D printing makes personalized design possible

Due to the development of modern product CAD technology, 3D printing is more flexible and flexible. Products that meet the requirements can be designed and processed according to consumers' personal needs, making personalized design and production possible and truly people-oriented.

2. 3D printing makes product shape design more diverse

Combined with CAD, 3D printing can use free curve surfaces to generate product shapes and print them out. Therefore, it is qualified to be more diversified in the shape, structure, and other aspects of products. Designers are less restrained when designing product shapes (Wang Lina, Chen Lin, 2018).

3. 3D printing expands the idea of product structure design.

3D printing makes the product structure very complicated, and the trend of product structure and shape design integration gradually emerges. It can directly generate complex parts shapes and structures without splitting or integrating product structures. It not only improves production efficiency but also improves the structural strength, rigidity, and reliability of the product.

3 CONSTRUCTION MODE OF ENGINEERING GRAPHICS COURSE USING 3D PRINTING TECHNOLOGY

The theory, methods, and means of human design and manufacturing products were closely related to the level of scientific and technological development at that time. If there is any product manufacturing method, there will be a corresponding product design theory and method (Zhu Yanqing, 2015). For example, for the material reduction manufacturing method, we add some common structures to strengthen strength, stiffness, and manufacturing requirements according to the functional requirements of parts. Try to make the shape of the product simple for processing. In terms of structure consideration, it is possible to decompose the complex parts of the structure into relatively simple parts to facilitate processing and production. Then connect the parts to the components. And based on this idea, a set of design methods and design specifications have been formed. The engineering graphs course is also taught according to this specification

3.1 The Impact of 3D Printing Technology on the Teaching of Engineering Graphics Courses

3D printing is a method of additive manufacturing. When using 3D printing for product design, the main points to be considered are different from that of reduced material manufacturing. For example, in the shape design of parts, the free curve surface is used to define the surface, which can not only meet the aesthetic requirements, but also meet the application requirements such as actual working space and strength stiffness, and save materials. At the same time, to meet the needs, the complex shapes of the parts can be printed at once without having to decompose them into multiple parts through connection. New structural products can be designed, which are light, material-saving, and high in strength and stiffness (Xia Duanwu, Xue Xiaofeng, 2016). And some of these design ideas and methods were not available in the previous component design, and there was no corresponding content reflected in the course teaching of engineering graphics (Zhou Yi, Xiao Yang, 2015). Through careful analysis and research, considering the characteristics and applications of 3D printing, we have the following considerations about the teaching of the engineering graphs course:

- Appropriately reduce the traditional graphic education content, and try to start the organization and learning of the course content with the 3D objects;
- In the introduction of the generation mode of three-dimensional objects, the concepts and expressions of modern three-dimensional modeling theory are introduced. In addition to the traditional combinations, the 3D modeling methods such as stretching, rotation, scanning, and free curve surface generation are introduced, and these methods are also introduced to the component configuration design;
- Strengthen the introduction and use of 3D design software, and use the software to skillfully turn design ideas into 3D models through the practice of teaching experiments;
- Add the teaching and training of content that changes the structural design methods and ideas of relevant parts due to the characteristics of 3D printing.
- Appropriately reduce the content when the three-dimensional object is projected to the plane to get the projection. Some efficient editing techniques for two-dimensional views are introduced to facilitate the generation of engineering drawings that meet national standards.
- Appropriately reduce the content of two-dimensional graphic drawings, and directly use 3D software to project the floor plan.
- Deeply integrate practical teaching links with classroom teaching links. We will break through the gap between theoretical, practice, component design, and expression, and the generation of final real objects, to truly achieve what you see is what you get and what you want.
- Make full use of computer-aided education in teaching design. Teachers will design the online course resources and publish them through the online course platform. Students will receive learning tasks and obtain learning resources for independent learning. Throughout the learning process, students can communicate and interact with teachers and other peers on time through online course platforms or other communication tools.

3.2 The Relationship and Impact of 3D Printing Technology and the Practical Teaching Link of Engineering Graphics Courses

Teachers mainly focus on thinking development and comprehensive practical learning activities and carry out seminar-oriented teaching and research-oriented teaching. The main teaching tasks include three aspects: first, answering questions and solving questions in the classroom for difficult and common problems encountered by students in the process of online self-study, and organizing students to discuss in groups, a study in groups, and encourage students to divergent thinking; second, arrange special experiments and comprehensive experiments, carry out research teaching, and cultivate students' Design thinking, innovative thinking and the ability to comprehensively apply the knowledge and skills learned to solve practical engineering problems; third, evaluate students' learning results. Students’ learning tasks include: first, asking questions, bringing difficult problems encountered in the online self-study process to the classroom, and actively participating in group discussions; second, carrying out group cooperative learning and research learning with other companions under the guidance of teachers to complete thematic tasks; third, summarize and report on research results.

Due to the development and maturity of 3D printing technology, makes it easy for us to design complex objects and get actual parts quickly. In this way, hands-on sessions can be added during the course. Connected with the established mechanical innovation design laboratory, 3D printing equipment is used to enable students to complete the configuration, design, and expression of objects to the direct output of 3D printing models, to achieve the purpose of comprehensive application and training of students' knowledge (Zhou Yi, Xiao Yang, 2015). Based on this consideration, in the mode of Computer Aided Education for engineering graphic teaching process, we have designed the practical teaching frame, shown in Figure 1. And the construction of laboratory software and hardware conditions has been carried out.

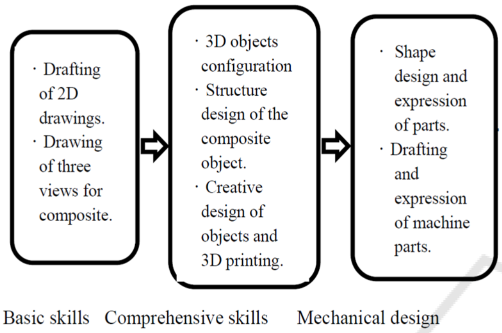


Figure 1: The practical teaching system framework.

This deep integration of classroom teaching and practical teaching has been carried out in the past two years of engineering graphics courses, and the effect is good (Liu Ying, Li Kai, Cao Mo, Li Yuyi, 2017). Students reflect that through such experiments, what they design objects are what they see, are impressed with, and have a solid grasp of what they have learned. Figure 2 is the laboratory, and Figure 3 is the experimental results of students' 3D modeling.

Figure 2: Course teaching laboratory.

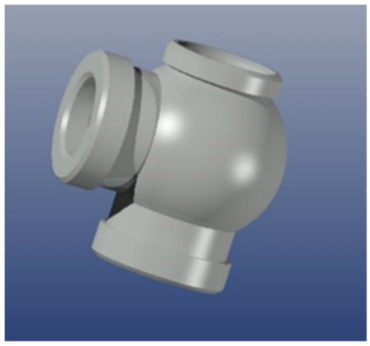


Figure 3: Student 3D modeling result.

4 COMPUTER-AIDED EDUCATION AND THE CULTIVATION OF STUDENTS' INNOVATIVE ABILITY

Student-centered, focusing on strengthening the training and cultivation of students' innovative ability in teaching has always been a very important teaching purpose. In the process of the computer-aided education project, we have done the following to cultivate students' innovative abilities in the teaching process:

- Adopt discussion teaching. Ask some questions for students to find their answers for discussion, and the teacher guides them. For some content, give some directions and ideas, so that students can try to study and answer them. In the teaching process, teachers pay attention to the role of needle threading, control, and guidance. Let all students participate in it. Through this process of exercise, they can quickly adapt to future college studies.
- Carry out research-based teaching. Use the generation methods of various shapes to construct different shapes and discuss their projections, which not only trains innovation ability but also increases the training of students' spatial imagination ability. Students are required to complete their homework in the form of a report after class, which can be discussed and completed together in groups.
- Use the characteristics of 3D printing to carry out the creative design of object configuration and print output. Give questions, let students create as many shapes as possible through the knowledge they have

learned, experience the fun of creativity, and experiment with printing and output. I use the theoretical knowledge I have learned and mastered the hands-on link of practice. What I see is what I get.

- Use the advantages of education informatization for real-time review and coaching communication without time or space restrictions. Micro classes have been made. And an engineering graph learning resource has been established to enrich students' learning.

5 RESULTS AND SIGNIFICANCE

The teaching effect of the course is evaluated through comparison. In the second and third years of the reform, the results will be reflected through the statistical analysis of performance statistics and questionnaires after the completion of the class study of the same school hours and the same requirements (Xiao Yang, 2017). Specific evaluation methods: First, compare and analyze students' course examination results in the two academic years before and after the computer-aided education mode of the course, test students' mastery of course knowledge, and evaluate the teaching effect relatively objectively; second, compare the design and expression ability, teamwork ability and shape of the two teaching models to students. The impact of the improvement of ability and quality such as physical innovation and conception ability to verify the effect of computer-aided education.

By the principle of overall sampling and strict control of differences between groups, 60 students were selected from each of the two academic years before and after the computer-aided education mode as the object of investigation and analysis, that is, 60 people from the reform teaching group (referred to as the computer-aided education group) and 60 people from the traditional teaching group (referred to as the traditional group).

Both groups of elective students come from the same department, and the same grade, and the student foundation and the content of the previous courses are the same. The specific analysis of the curriculum results and ability improvement of the two groups of students is as follows:

5.1 Course Results Analysis

Judging from the course results of the two groups of students, there are obvious differences between the computer-aided education group and the traditional group in terms of average score, variance, and excellent rate. The average score of the computer-aided education group was nearly 10 points higher than that of the traditional group. The score variance of the computer-aided education group is 5.1, and the traditional group is 11.3. The variance of the computer-aided education group is about half that of the traditional group, indicating that the individual score difference of the computer-aided education group is significantly reduced. Judging from the excellent rate (the proportion of course scores of more than 90 points), the excellent rate of computer-aided education teaching group students is significantly higher than that of the traditional teaching group, with an overall increase of 13.3%. The results of the specific analysis are shown in Table 1.

Table 1: Comparison of the academic performance.

Group	Number of examiners	Average performance	Performance variance	Excellence rate
CAE group	60	78.9	5.1	23.3%
Traditional group	60	69.6	11.3	12%

The analysis results of the schoolwork transcript factor difference between the reform group and the traditional group also show that there is a significant difference between the computer-aided education group and the traditional group. That is, at the level of a=0.05, the p-value is 0.00012, which is far less than 0.01.

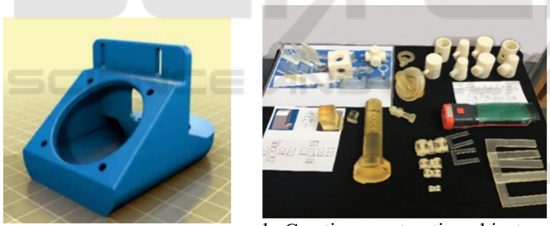
The above results show that: Computer-aided education pays attention to the combination of online and offline, emphasizing a new teaching model such as research teaching and cooperative learning, which is conducive to generally improving students' understanding and mastery of knowledge and skills, reducing individual differences among students, and effectively promoting the individual academic performance of each student. The improvement. Compared with traditional teaching, computer-aided education can achieve better teaching results in knowledge transfer and skills training.

5.2 The Improvement Ability Analysis

According to the educational goals of this course, students' ability literacy mainly includes 7 parts: students' ability to understand and effectively use what they have learned, engineering design ability, ability to analyse and solve problems, innovative thinking ability, expression and communication ability, teamwork ability and self-study ability. Through a questionnaire survey of students from CAE groups and traditional groups, it is found that the above-mentioned ability factors of CAE teaching group students are significantly better than that of traditional teaching groups. The details are shown in Table 2.

Through three years of teaching research and reform practice, this project has carried out and completed the following tasks:

1. The study explores the impact of the application of 3D printing technology on the teaching content of engineering graphics courses, and establishes a curriculum system corresponding to it.
2. The study explores the experimental teaching link of engineering graphics that is deeply integrated with 3D printing and educational informatization. A relatively complete curriculum experimental teaching system has been initially established. The deep integration of experimental teaching content and classroom teaching content deepens students' understanding and application of book knowledge and is conducive to the smooth progress of the teaching process. Figure 4 shows the experimental results of the students.



a. Machine part b. Creative construction objects

Figure 4: Students' course experimental results.

The study explores the method of using 3D printing technology to cultivate students' innovative abilities. Figure 5 shows the data of the seven ability element indicators of the two groups of students after completing their studies. The CAE group is higher than the traditional group. The development and application of information technology will change our scientific and technological development and life, and will also have a great impact on higher engineering education. It should be said that the development and application of 3D printing technology have changed the manufacturing mode of a large class of mechanical products, and will also produce many new application fields and application results. Teaching reform focusing on the impact and requirements of these new technologies on the curriculum can improve the quality of teaching and meet the growing talent requirements of science, technology, and the economy for institutions of higher education.

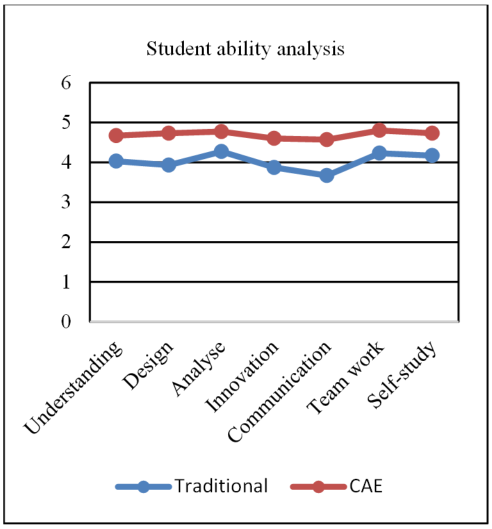


Figure 5: Student ability analysis.

6 CONCLUSIONS

After nearly three years of reform and practice, the teaching effect of the project is good. Students have achieved excellent results in mechanical innovation design competitions and 3D innovation design competitions in Sichuan Province and the whole country. The 2019 Asia-Pacific Graphic Forum was held at the University of Tokyo, Japan, and some of the results of the project were exchanged with international counterparts (Xiao Yang, Hang Chuan-jun, 2017).

3D printing technology is a modern technology that has only been widely used in this century. It will have a revolutionary impact on the manufacturing and production mode of products and deeply affect the manufacturing industry. It will also have an impact on the teaching and talent training methods of relevant majors in relevant colleges and universities. 3D printing technology is still developing continuously, and its deep integration and practice of corresponding courses in colleges and universities is also a new topic. Studying the theory and practice of deeply integrating information technology with the teaching of specific engineering graphics courses is necessary.

The times are developing, science and technology are developing, and students' abilities, quality, and requirements are also developing. Therefore, teaching reform must keep pace with the times and keep pace with development. For students, we must consider the impact of the current growth environment on them. Considering the impact of information technology on our lives, in the Internet era, students' social methods have changed, and there are many new modern teaching methods. What impact will the introduction and application of these teaching methods affect the teaching of engineering graphics? And the effect deserves further discussion and research.

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APPENDIX

Table 2: Variance analysis.

Ability factors	Teaching mode	Student self-evaluation					
		Very disapproval	disapproval	same	approval	Very approval	Mean value
Knowledge comprehension and application ability	traditional group	0(0.00%)	0(0.00%)	8(26.67%)	13(43.33%)	9(30%)	4.03
	CAE groups	0(0.00%)	0(0.00%)	1(3.33%)	8(26.67%)	21(70%)	4.67
Engineering design ability	traditional group	0(0.00%)	2(6.67%)	8(26.67%)	10(33.33%)	10(33.33%)	3.93
	CAE groups	0(0.00%)	0(0.00%)	1(3.33%)	6(20%)	23(76.67%)	4.73
Analytical and problem-solving ability	traditional group	0(0.00%)	1(3.33%)	3(10%)	13(43.33%)	13(43.33%)	4.27
	CAE groups	0(0.00%)	0(0.00%)	0(0.00%)	7(23.33%)	23(76.67%)	4.77
Innovative thinking ability	traditional group	0(0.00%)	0(0.00%)	10(33.33%)	14(46.67%)	6(20%)	3.87
	CAE groups	0(0.00%)	0(0.00%)	0(0.00%)	12(40%)	18(60%)	4.6

Express communication skills	traditional group	0(0.00%)	1(3.33%)	13(43.33%)	11(36.67%)	5(16.67%)	3.67
	CAE groups	0(0.00%)	0(0.00%)	0(0.00%)	13(43.33%)	17(56.67%)	4.57
Teamwork ability	traditional group	0(0.00%)	1(3.33%)	1(3.33%)	18(60%)	10(33.33%)	4.23
	CAE groups	0(0.00%)	0(0.00%)	0(0.00%)	6(20%)	24(80%)	4.8
Self-taught ability	traditional group	0(0.00%)	1(3.33%)	3(10%)	16(53.33%)	10(33.33%)	4.17
	CAE groups	0(0.00%)	0(0.00%)	0(0.00%)	8(26.67%)	22(73.33%)	4.73