



# Research on the Promotion Effect of Additive Manufacturing Technology on Mechanical Drawing Course of Vocational Education

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## Abstract:

The long-standing problem in the teaching of Mechanical Drawing is the low level of learning motivation. In order to solve this problem, the research group deeply analyzed the examination results of the previous students and put forward a teaching reform method of integrating additive manufacturing technology into Mechanical Drawing courses. The teaching reform method has been applied to teaching practice and has achieved good results. Firstly, the students are attracted by the display of the parts manufactured by additive manufacturing technology, and their enthusiasm for learning has been significantly improved. Secondly, in order to print out the works, the students discuss and analyze with each other. Thirdly, we used the finite element analysis software to carry out mechanical simulation of large-forced parts to show the trend of pressure and displacement. The statistical results of the examination results show that after the adoption of the new teaching method, the average score of the class examination is 72.20, which is 6.95 higher than the original score. The variance of scores has been reduced from 17.53 to 11.19, indicating that the score gap between students has decreased. The introduction of additive manufacturing technology and equipment in Mechanical Drawing courses is a typical teaching model combining theory with practice, therefore it should be adopted in more vocational colleges and universities.

**Keywords:** Mechanical Drawing, additive manufacturing, teaching application, vocational colleges.

## 1 INTRODUCTION

Higher vocational education is produced by “adapting to the needs of modern economic and social development and technological progress, and industrial development to a certain stage”, which is the inevitable development of the market economy [8]. The high-quality development of vocational education is an inevitable trend in the development of China’s education in the new era, which is the basic direction of the development of vocational education put forward by the national “14th Five-Year Plan” and Vision2035, and it is also the inherent attribute and essential requirement of the development of vocational colleges and universities themselves [4] [7]. Vocational education has the dual function of “enabling everyone to obtain the supply of life according to their personality, develop their abilities,

and fulfill their obligations to the group at the same time”, which is in line with the characteristics of vocational education is to apply what they have learned and serve the society.

Mechanical Drawing is an important technical basic course required for engineering, especially mechanical majors, and it is a course to study the drawing (drawing) and reading (looking) laws and methods of mechanical drawings [2]. Mechanical drawing is the language of the engineering, which is an important tool for communicating and expressing technical ideas, and it is an important technical document for the engineering and technical departments of enterprises [3]. Mechanical Drawing teaching has a core position in the mechanical industry, and it can cultivate manufacturing talents with drawing reading and Drawing ability [1]. Mechanical Drawing course is the professional language and

communication mode of the machinery industry, which is of great significance to the training of senior engineers and plays a key role in cultivating outstanding engineers [5].

The content of the course is relatively abstract, which means it is difficult for students to fully grasp the content only by understanding the content of the teacher’s teaching through the classroom, without homework exercises after class; it is difficult to combine the course content with the drawings of factory production practice (mechanical parts drawings, assembly drawings) content because of the lack of double qualified teachers and less contact with the enterprise [6]. Teachers pay too much attention to the learning of the principles and methods of “drawing” and “reading pictures”. It is difficult for teachers and students to communicate with each other, and the classroom atmosphere is not active, which makes it difficult for students to expand their knowledge and stimulate their interest in learning [9].

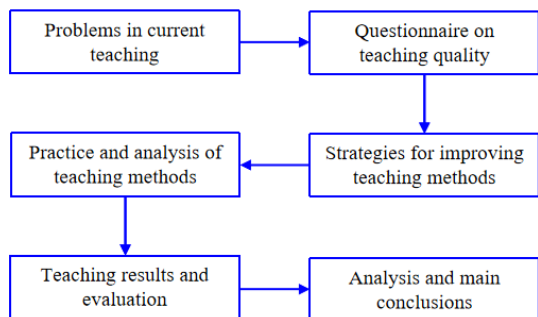


Figure 1: The research logic diagram of the paper.

In view of the lack of Mechanical Drawing course content, single teaching methods, boring and tedious students in class, the reform research and analysis of the course content and teaching methods of the Mechanical Drawing course were carried out. Based on digital documents, by using 3D printing instead of traditional processing and FDM molten material accumulation technologies, the actual production and processing of products were gradually constructed through the growth of materials layer by layer printing. The students’ learning interest was stimulated by the use of practical models. The complex and boring problem of Mechanical Drawing basic teaching in the traditional teaching mode was solved by the intersection and integration between disciplines and disciplines break the boundaries between disciplines to enhance students’ spatial imagination ability and thinking innovation ability. The research logic of this paper is shown in Figure 1.

## 2 Analysis of Learning Problems

### 2.1 Achievement Analysis

The examination papers of the mechanical drawing 8 chapter of 40 people in a class last class were analyzed. We have taken ten as one file to count the distribution of students’ achievements, and the statistical results are shown in Figure 2. As shown in Figure 2, the students’ grades fluctuate greatly. Two students with a score of more than 90, with a maximum score of 93. There are two students with less than 30 points, and the lowest score is only 26. The average score, variance and variation coefficient of the students are calculated. The calculation formula is as follows:

$$\mu = \frac{\sum x}{N} \tag{1}$$

$$\sigma^2 = \frac{\sum_{i=1}^N (x_i - \mu)^2}{N} \tag{2}$$

$$c_v = \frac{\sigma}{\mu} \tag{3}$$

According to the formula, the average score of all students is  $\mu_1=65.25$ , the variance is  $\sigma_1=17.53$ , and the coefficient of variation is  $C_{v1}=26.87\%$ .

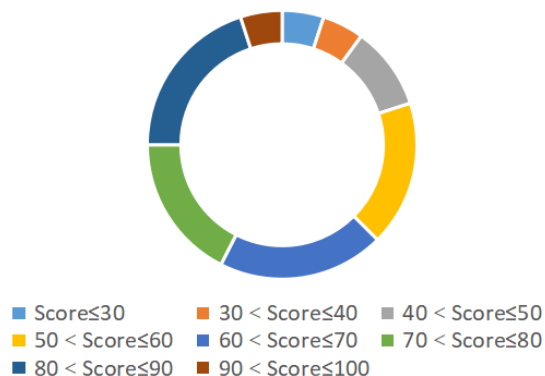


Figure 2: The statistical map of students’ achievements distribution.

The 26 students who passed were counted. The average score of the students was  $\mu_2=75.71$ , the variance was  $\sigma_2=10.17$ , and the coefficient of variation was  $C_{v2}=13.44\%$ .

The rules shown by the whole class are: firstly, the average score is low. Secondly, the variance is too large and the coefficient of variation is too high. The average score of the passing students has been significantly improved, and the coefficient of variation has changed to half of the original.

## 2.2 Questionnaire

In order to deeply analyze students' problems and improve the quality of teaching, questionnaires were conducted in the form of online voting. The questionnaire includes three questions. A have no interest and motivation to learn; B don't know what's the use of learning this course; C is too difficult to learn; Teacher D is not responsible. The statistical results of the questionnaire are: A 18 votes, B 13 votes, C 7 votes, D 2 votes.

It can be seen that the students are not interested in mechanical topics, which is the most important reason affecting everyone's study and examination results. In addition, attention should be paid to learning and application, and this course should be linked to subsequent courses such as mechanical manufacturing.

Improving the students' interest in learning, motivation and application are factors that must be considered in teaching reform.

## 2.3 Response Strategy

In order to improve the quality of teaching and reduce the variance of test scores, this study puts forward a plan to introduce additive manufacturing and form a study group. The purpose of introducing additive manufacturing is to improve interest in learning. The main purpose of the study group is to drive poor students. The main implementation process is shown in Figure 3.

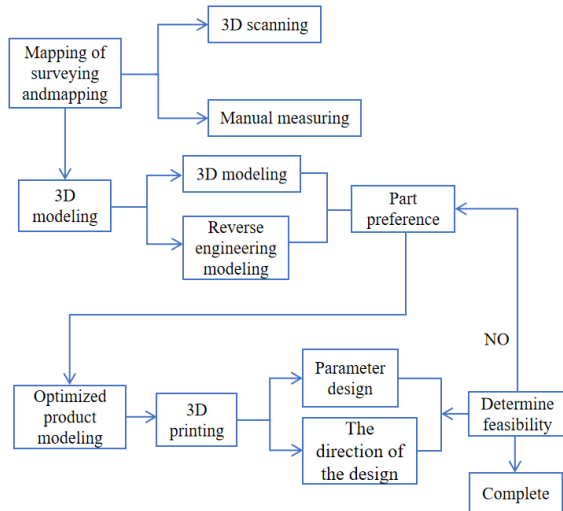


Figure 3: The logic diagram of Implementation process.

## 3 ADVANTAGES OF ADDITIVE MANUFACTURING TECHNOLOGY

Based on digital models, using powder-bonded materials or melt-able resins as raw materials, Additive manufacturing is an emerging manufacturing technology that creates physical objects by layer-by-layer build-up.

Additive manufacturing technology breaks the limitations of traditional manufacturing, simplifies the molding process, shortens the manufacturing cycle, and can fully display the imagination of designers and expand students' imagination and design capabilities.

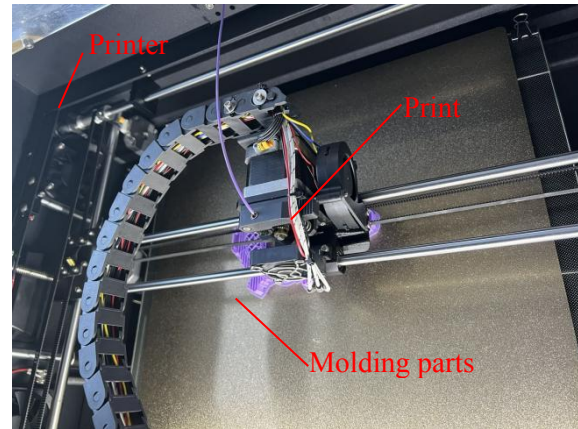


Figure 4: 3D Printer.

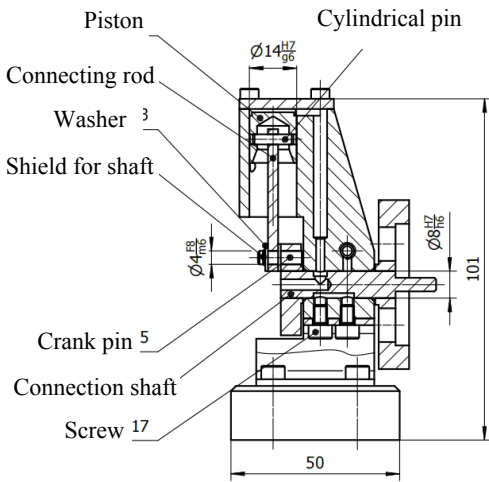
As an emerging technology, additive manufacturing was introduced into the mechanical manufacturing drawing course, which improved the students' spatial imagination, drawing ability and professional level, allowing the students to experience the innovation brought by 3D printing, which is further stimulate students' interest in the industry. Firstly, in the modeling stage, the students use modeling software to convert the two-dimensional drawings into three-dimensional drawings, which display the drawings intuitively, and exercise the students' ability to read drawings and spatial imagination. Then, in the 3D printing stage, the data model is input into the slicing software, and the parameter setting of the printing process and the adjustment of parameters between parts and fittings is completed. The students' printing process is shown in Figure 4. The students gradually print out the three-dimensional model according to their own design concepts and needs, and improving the students' interest in learning the drawing course and the new technology of 3D printing.

## 4 TEACHING APPLICATION

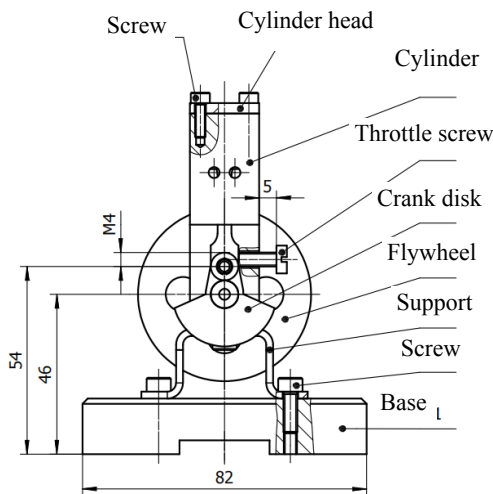
### 4.1 Observation of Additive Manufacturing Parts

Select a simple model commonly used by the enterprise, such as the assembly diagram of the piston air motor in Figure 5. By arranging a drawing class, the students process the drawings through the enterprise parts, and disassemble and draw the three-dimensional model of each part from the assembly drawing. By analyzing the assembly and motion relationship between various parts, students will be familiar with the basic theoretical knowledge they have learned in practice, and

have a preliminary grasp of picture reading, drawing skills and precautions.



(a)

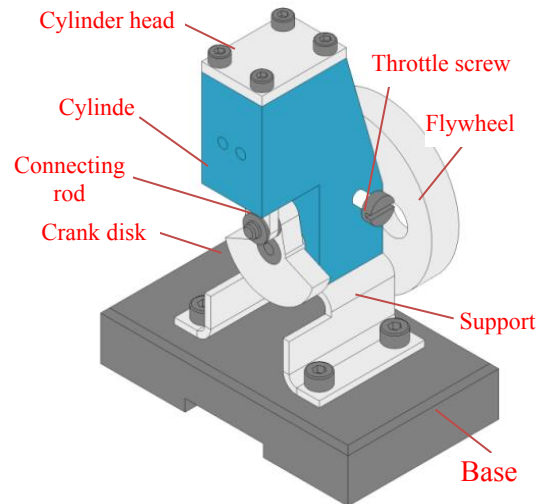


(b)

**Figure 5:** Assembly drawing of Piston Air Motor: (a) view A; (b) view B.

**4.2 Use 3D Drawing Software to Draw Part Model and Complete Assembly**

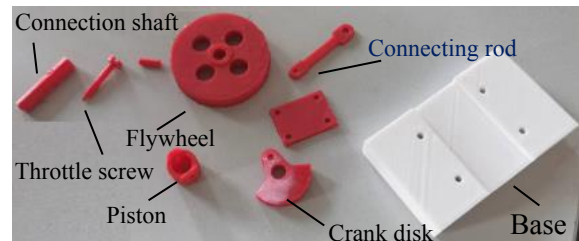
According to the assembly drawing shown in Figure 5 and the two-dimensional engineering drawing, the students can discuss in groups, divide labor and cooperate, carry out 3D modeling on the basis of correct image recognition. The students complete the drawing of each part of the piston startup motor part through 3D design software Autodesk Inventor, and then complete the assembly of components. As shown in Figure 6, the students observe the relationship and cross-sectional view of each component. It is helpful to understand the working principle of the piston air motor.



**Figure 6:** 3D assembly drawing of piston air motor.

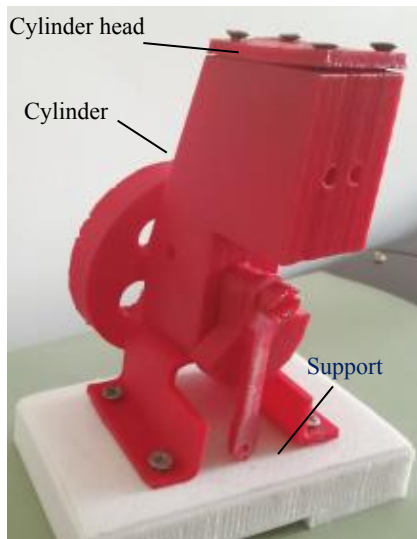
**4.3 Printing of Works**

The teacher have introduced 3D printing technology in detail, so that the students could have a preliminary understanding of the characteristics and advantages of 3D printing, and fully stimulate the students' interest in exploration. A set of models with the most accurate 3D modeling was selected, imported into the slicing software in STL format, set the appropriate scale, precision and temperature, and selected the appropriate direction as the support part of the model for printing. The actual object is shown in Figure 7. Through additive manufacturing practice, the students are guided to consider material savings and optimized structure when designing products, which stimulate the students' innovative thinking, give the students a practical understanding of processing production and manufacturing processes, and prepare for future work in enterprises.



(a)





(b)

**Figure 7:** 3D actual object: (a) part diagram; (b) assembly drawing.

#### 4.4 Introducing the Designed Works into the Classroom to Feedback Teaching

The 3D printing model assists the teaching of reading assembly drawings, and is used for teaching model of engineering assembly drawings. By observing the model, the students can more intuitively understand the assembly relationship of each part of the model. Besides, the students can better grasp the standard parts and parts distinction involved in teaching, the content of assembly drawings, the methods of reading assembly drawings, disassembling and drawing part drawings, and the ability of parts surveying and mapping.

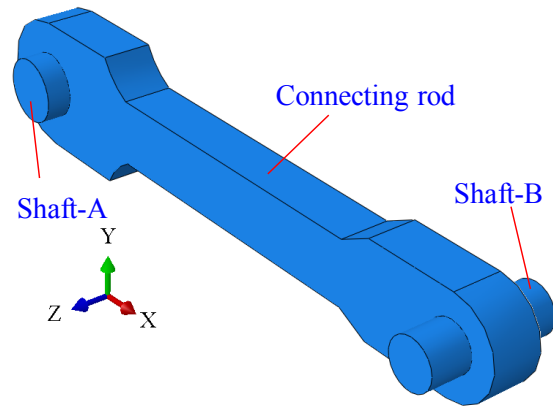
#### 4.5 Knowledge Development

In the process of practical application, the students asked how much torque such a thin connecting rod can withstand and whether there will be a fracture phenomenon. Based on this problem, the research team uses finite element analysis software to analyze the force change of the connecting rod and help students intuitively observe the change.

### 5 MODELING AND SIMULATION

#### 5.1 Modeling

To solve the students' problems, a finite element model was established. The model consists of three parts, namely the Shaft-A, the Shaft-B and the Connecting rod, as shown in Figure 8. The geometry of the model is the same as described above.



**Figure 8:** Finite element model after meshing and its coordinate system.

In the “Part” command, the surface of the Shaft-B is named “Surf-1”. The inner surface of the hole connected to Shaft-B is named “Surf-2”, while the inner surface of the hole connected to Shaft-A is named “Surf-3”. The surface of the Shaft-A is named “Surf-4”.

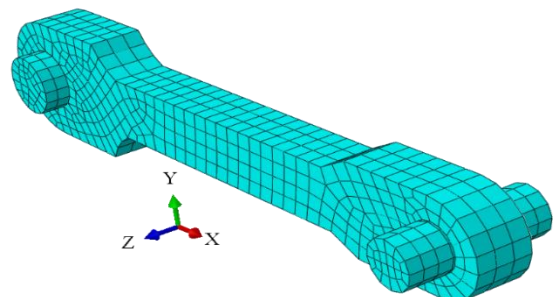
In the “Interaction” command, the point RP-1 (-50, 0, 1.5) is created in order to set “Load”, while the point RP-2 (-10, 0, 1.5) is created in order to set “Boundary condition” more reasonably. The Shaft-A and the Shaft-B are set as “Rigid body”. The Shaft-A is bound to the point RP-2. The Shaft-B is bound to the point RP-1.

In the “Tie” command, the “Surf-1” (as the active surface) is glued to the “Surf-2” (as the driven surface). The “Surf-3” (as the active surface) is glued to the “Surf-4” (as the driven surface).

In the “Element type” command, C3D8R element type selected for the whole model. In the “Mesh” command, the edges of the model are “seeded” respectively so as to generate a more reasonable grid. The model after meshing is shown in Figure 9.

In the “Properties” command, the density of the material is  $\rho=8 \times 10^3 \text{ kg/m}^3$ . The elastic modulus of the model is  $E=210 \text{ GPa}$  and the Poisson's ratio is  $\mu=0.3$ .

In “Boundary condition” command, all six degrees of freedom of the RP-2 is constrained. A force  $F=500 \text{ N}$  along the X-axis is applied at point RP-1.



**Figure 9:** Finite element model after meshing and its coordinate system.

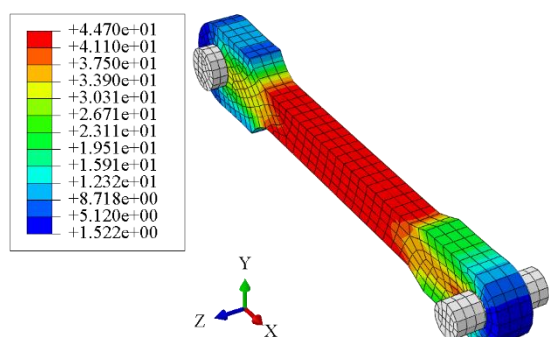


Figure 10: Mises stress nephogram of the model.

## 5.2 Simulation and Analysis

The model is simulated on a computer. Relevant nephograms and rich data are obtained. The Mises stress distribution of the model is studied and the Mises stress nephogram is shown in Figure 10. Different colors represent different stress values (the redder the color, the greater the stress value). Figure 11 shows that the stress distribution of the model is not uniform. The Mises stress in the middle of the rod is larger and more uniform. The maximum Mises stress value was 44.70 MPa. The Mises stress is small in the part close to the two shafts. Minimum Mises stress occurs at both ends of the rod.

Since the force is applied in the X-axis direction, the displacement ( $U_1$ ) in the X-axis direction is studied. The  $U_1$  nephogram of the model is shown in Figure 11. Figure W shows that the distribution of  $U_1$  values is layered.  $U_1$  gets bigger and bigger as we go along the X-axis. As can be seen from the annotation chart, the maximum value of  $U_1$  is  $5.777\mu\text{m}$ .

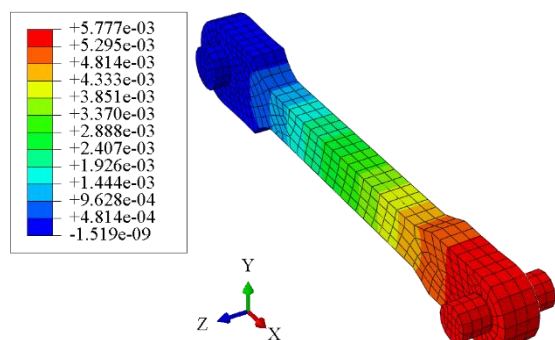


Figure 11:  $U_1$  nephogram of the model

## 6 TEACHING PRACTICE AND ANALYSIS

### 6.1 Achievement Analysis

After introducing additive manufacturing technology into mechanical drawing courses, the research team updated the existing teaching model and carried out teaching practice. The examination papers of Chapter 8

of the mechanical drawing of 30 people in a class this year are analyzed. Taking ten as one file, the distribution of students' achievements is statistically calculated, and the statistical results are shown in Figure 12.

As shown in Figure 13, the students' grades are less volatile. One student with a score of more than 90, with a maximum score of 91. There are 4 students who failed, and no students with a score of less than 30. Similarly, the average score, variance and coefficient of variation of the students are calculated, and the average score of all the students is  $\mu_3=72.2$ , the variance is  $\sigma_3=11.19$ , and the coefficient of variation is  $C_{v3}=15.5\%$ .

The 26 students who passed were counted. The average score of the students is  $\mu_4=75.58$ , the variance is  $\sigma_4=6.84$ , and the coefficient of variation is  $C_{v4}=9.04\%$ .

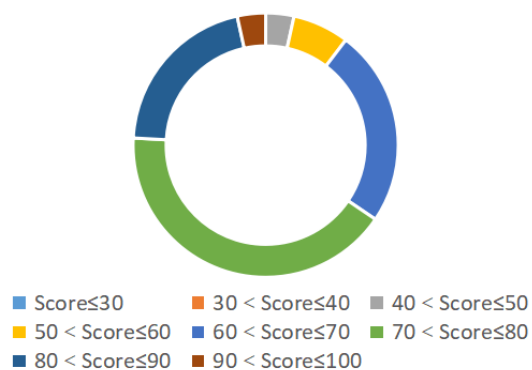


Figure 12: The statistical map of students' achievements distribution.

It can be seen that the introduction of additive manufacturing technology has greatly improved the students' passing rate, and the score distribution variance, variation coefficient and other data have been reduced to the original general, indicating that the fluctuation of the students' grades is relatively small, the scores are relatively stable, and the variation coefficient has also been reduced to half of the original. Teaching practice shows that the innovation of the teaching model is successful.

Firstly, the students' interests have increased, and their learning motivation has increased. The classroom used to be dominated by teachers' teaching, but now the teachers and students participate together to improve hands-on practice. Teachers believe that the learning effect has been significantly improved.

Secondly, 3D models and 3D printed physical objects are more convenient for the students to understand various elements in Mechanical Drawing (such as axial mapping, profiling, section diagram), which has played a positive role in promoting the cultivation of drawing ability and spatial thinking ability.

Finally, by introducing the new technology of additive manufacturing and finite element analysis, we have expanded our knowledge, and gained a deeper

understanding of subsequent professional disciplines and discipline systems.

## 6.2 Evaluation of Teaching Quality

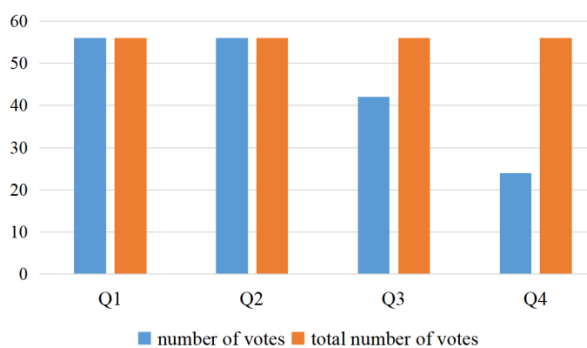
In order to scientifically evaluate the teaching model, the research team conducted a questionnaire on the teaching experiment. 56 students participated in the questionnaire. The questions covered in the questionnaire are as follows:

Q1: have the additive manufacturing technology enhanced your interest in learning?

Q2: have the additive manufacturing technology more clearly shown the internal structure of the machine and make it easier to read the drawings?

Q3: have the additive manufacturing technology helped you understand of the preciseness of Mechanical Drawing: design determines product quality?

Q4: have the additive manufacturing technology expanded knowledge and improved comprehensive ability?



**Figure 13:** Statistics of questionnaire survey.

The students' votes were sorted and counted. The statistical results are shown in Figure 8. As can be seen from Figure 13, Q1 get 56 votes. All of the students who participated in the questionnaire believe that the application of additive manufacturing improves their interest in learning. Similarly, the vote rate of Q2 was 100%. All students believe that the application of the additive manufacturing technology more clearly shown the internal structure of the machine and make it easier to read the drawings. In addition, some students recognized the introduction of software and opened up their own horizons.

However, the number of students who voted for Q3 was 42 (accounted for 75%), and Q4 was 24 (accounted for 42.9%). In order to further improve teaching quality, the research team communicated with the students. They believe that these digital technology can help them more intuitively understand the laws of bending. Students' opinions should be taken into account. To improve students' learning efficiency and interest, teachers at vocational schools should work in more fields. In

addition to additive manufacturing technology, more new technologies should be considered in the teaching. Only through continuous attempts and improvements can the teaching quality of Mechanical Drawing be improved.

In a word, the application of additive manufacturing technology improves the students' interest in learning and the quality of teaching. The application of additive manufacturing technology in Mechanical Drawing should be further explored.

## 7 CONCLUSIONS

Mechanical Drawing is an important professional basic course, the application of introducing the additive manufacturing technology into the teaching of Mechanical Drawing has gradually changed the traditional teaching methods in the past. Printing out the physical model by using the additive manufacturing technology in the teaching process is beneficial to the students' better understanding of part drawings and helps to enhance students' interest in engineering drawing and improve the learning efficiency. At the same time, the mechanical tensile fracture phenomenon of the students' doubts is solved by using finite element simulation data. The simulation animation intuitively shows the neck shrinkage and cracking behavior of the tensile specimen, and the Mises stress cloud diagram clearly shows the stress distribution of the sample at different points in time. Firstly, the research group combined the results of the previous class to carry out data analysis, and used the probability statistical analysis method to obtain the law of score distribution and summarize the causes. Secondly, they brought many parts prepared by additive manufacturing method to the classroom and guided the students to use 3D design software Autodesk Inventor to complete physical 3D modeling. Finally, the students were required to print out the designed parts use the additive manufacturing equipment, the defective printed parts and problems existing in the early Mechanical Drawings have been studied and analyzed. Practice shows that the integration of 3D printing into the course teaching process of Mechanical Drawing not only can skillfully integrate the abstract theoretical knowledge and practical skills in the textbook, but also integrate the advanced technology into the teaching process. While the teaching content and methods have been enriched, the students' innovative thinking is easier been stimulated. The result is a good teaching effect, which is perfectly in line with the teaching purpose of the course.

## ACKNOWLEDGEMENTS

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