Application of Modeling and Simulation Technology in Vocational Education Skills Competition

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ABSTRACT

During the preparation of the skills competition, the students encountered the problem that the bending torsion combination experiment could not be implemented. In order to solve this problem, the paper proposed the idea of modeling and simulation. The students established a geometric model at the request of the teachers and put forward specific simulation requirements. On this basis, the finite element model was established by ABAQUS, and calculation was carried out on a computer. Clear Mises stress nephograms and rich data were obtained by the simulation, which solved the students' doubts and accelerated the production progress of the students' entries. In the process of solving the problem, problem analysis ability and data processing ability of the students have been significantly improved. The skills competition is an important part of the vocational education system. Simulation technology in the design of entries has been little studied and should be paid attention by more scholars.

Keywords: *simulation technology, modeling, skills competition, vocational education.*

1. INTRODUCTION

Vocational education and general education are two different types of education with equal importance. In recent decades, vocational education has provided strong talent support for China's economic and social development. As China enters a new development stage, industrial upgrading and economic structure adjustment are accelerating, and the demand for technical and skilled talents in all walks of life is becoming more and more urgent. Therefore, the important position and role of vocational education are becoming more and more prominent [1].

As is known to all, vocational education is positioned to cultivate skilled and applied talents. Different from classroom education, the preparation and competition process of skills competition pay more attention to the cultivation of students' operational ability and practical ability. At present, participating in and preparing for various skills competitions has become an important supplement to vocational education [5]. In 2019, nine departments including the Ministry of Education issued the "Vocational Education Quality Improvement Action Plan (2020-2023)", which clearly stated that vocational colleges should "play the leading role of promoting education and learning through competitions" [4]. As a good platform for vocational education to improve the vocational quality of students, the vocational skills competition not only strengthens the linkage between the government, industry, enterprises, and vocational colleges, but also promotes the continuous deepening of education and teaching reform, and has become an important effective means in comprehensively improving the cultivation quality of the technical and skilled talents [12]. The skills competition has a complete standard system, and a fair and just evaluation mechanism, and is the most direct way for vocational colleges to test the talent cultivation quality [10]. Integrating the content of the technique and skills competition into classroom teaching, on the one hand, can speed up teaching reform and build an education model for real job ability training; on the other hand, can enable teachers to improve professional theory and practical skills around the actual operation of enterprises [11].

In recent decades, vocational colleges pay more and more attention to skills competition, and the number of students participating in various competitions has increased sharply. Taking the Henan Provincial Competition of the "Internet+" College Student Innovation and Entrepreneurship Competition as an example, up to 288,000 students signed up in 2021 [2]. Different from undergraduate universities, vocational

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colleges lack experimental equipment, which affects the design and production of students' entries in innovative competitions. With the significant improvement of computer computing power and the rapid development of finite element software, simulation technology has been greatly developed in many fields, such as metallurgy [7][9], transportation, fire protection, medical treatment [3][6], military, and education [8]. However, the research and application of simulation technology in the field of design and production of entries in skills competition are very few. This research has actively explored in this field and achieved some research results. In this paper, the simulation technology is used to solve the problems encountered by students in preparing for the skills competition. The research logic is shown in Figure 1.

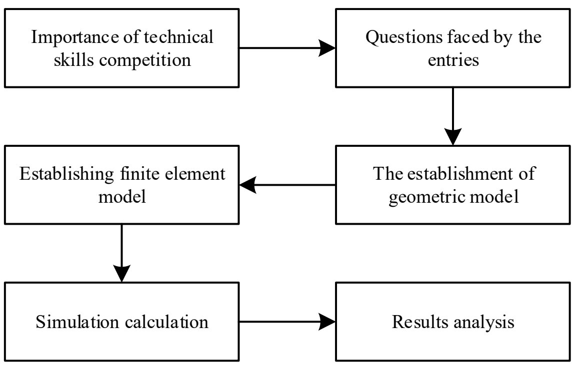
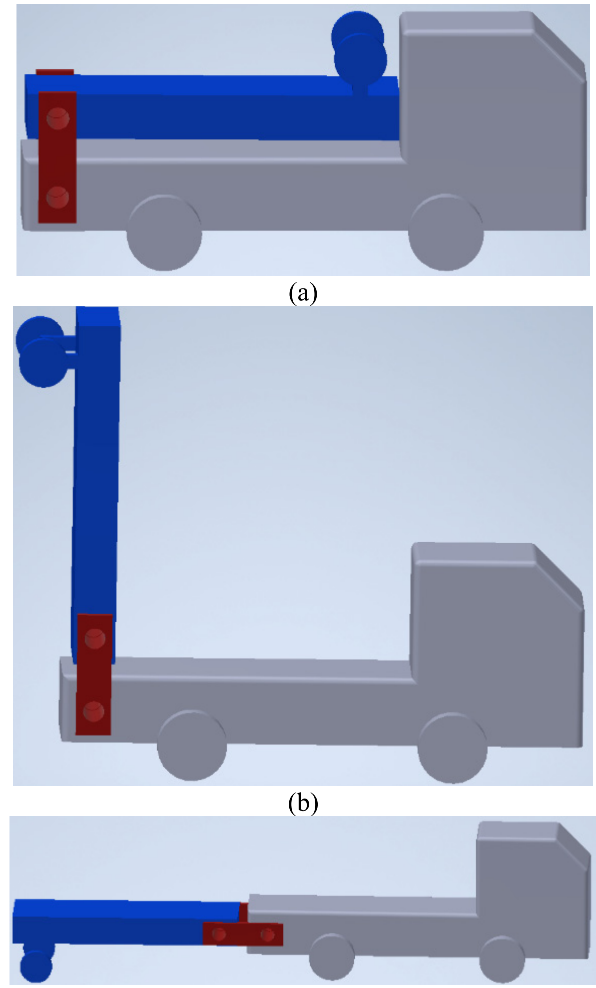


Figure 1: The research logic diagram of the paper.

In the process of solving the problem, problem analysis ability, expression ability, and data analysis ability of the students have been improved. The ideas of this paper are worth being applied to more fields of vocational education.

2. PROBLEMS ENCOUNTERED

In order to participate in the "Internet +" College Student Innovation and Entrepreneurship Competition, some students from Beijing Polytechnic formed a participating team. The students named their entries "Unmanned Disaster Rescue Vehicle". The application scenario of the entries is: transporting materials (such as medicines) in a dangerous environment. In order to improve flexibility and transportation capacity, the loading platform of the rescue trolley has folding function, as shown in Figure 2. In this way, when more materials need to be transported, the loading platform of the rescue trolley is opened, as shown in Figure 2 (c). When transporting less materials, the loading platform of the rescue trolley is folded, which improves the flexibility of the trolley, as shown in Figure 2 (a).



(a) (b) (c)

Figure 2: Schematic diagram of entries.

As shown in Figure 2, shaft-shank structure bears large loads. Under the action of external force, the shaft is under the combined action of bending and torsion. Obviously, excessive load will lead to serious plastic deformation and even fracture of the shaft, thus affecting the operation of the rescue trolley. In order to ensure the reliability of the entries, the team members hope to carry out a bending-torsion test mechanical experiment to test the stress distribution of the shaft. The students' solution and test requirements were recognized by the research team. However, it is a pity that the school does not have the relevant experimental equipment. In order to solve students' problems and promote the progress of the entries, the research team considered using finite element software for modeling and simulation calculation. Firstly, the research team introduced the basic theory of finite element and related software to the participating students. Later, Modeling and simulation work was performed by teachers and students.

3. MODELING

3.1. Geometric Model

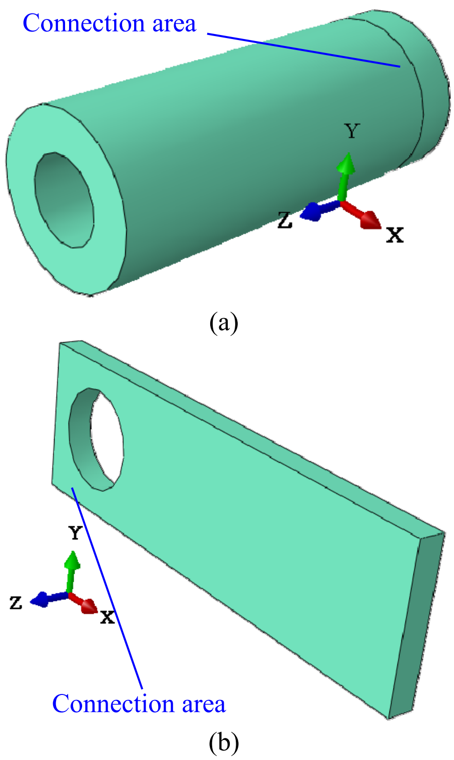


Figure 3: Shaft-shank structure used for simulation.

In order to exercise the problem analysis ability and drawing ability of the students, the task of establishing a geometric model was assigned to the students by the research team. The students used SolidWorks to draw the parts to be tested, as shown in Figure 3. The test component consists of two parts, one is hollow shaft, as shown in Figure 3 (a); The second is the handle, as shown in Figure 3 (b). The two are connected by the marked connection area in the figure. The parameters are as follows:

(1) The length of the hollow shaft is L=100 mm. The inner diameter is d=20 mm and the outer diameter is D=40 mm. The width of the connection area is 10 mm, which is consistent with the thickness of the shank.

(2) The length of the shank is S=200 mm, the height is H=60 mm and the thickness is t=10 mm. As shown in Figure 3 (b), a cylinder is cut off from the shank. The diameter of the cylinder is equal to the diameter of the shaft (D=40 mm). The axis of the cylinder is 30 mm away from both long side of the shank; the distance from the short side of the shank is 30 mm.

The test parameters of the students are as follows: the hollow shaft is fixed at one end away from the shank. The end of the shank away from the hollow shaft bears 5 kN, 10 kN and 15 kN forces.

The data to be measured are as follows: the stress distribution of the hollow shaft corresponding to each load.

3.2. Finite Element Model

According to the above dimensions, the finite element model was established by the research team using ABAQUS software. The material property of the two parts are set as follows: density of the material ρ=7.9×10^3 kg/m^3, elastic modulus E=210 GPa, and Poisson's ratio λ=0.3.

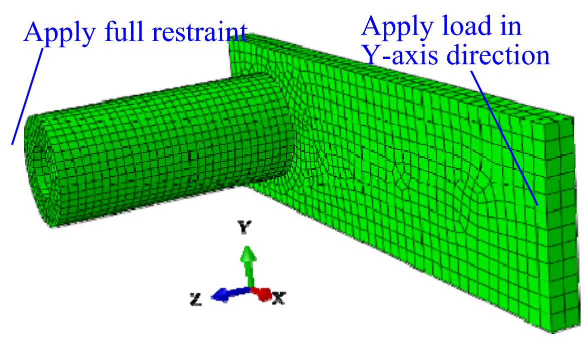


Figure 4: Finite element model after mesh generation.

The plastic deformation of the two parts are set as: σ_1=418 MPa, ε_1=0; σ_2=500 MPa, ε_2=0.0158; σ_3=606 MPa, ε_3=0.0298; σ_4=829 MPa, ε_4=0.25; σ_5=932 MPa, ε_5=0.55; σ_6=1040 MPa, ε_6=0.85.

Use the "Tie" command in the ABAQUS software to connect the hollow shaft and the shank as a whole. The application area of the "Tie" command is marked in Figure 3. In the ABAQUS software, "Element type" of each part is selected as C3D8R. "Approximate global size" of the shank was set as 5 mm, and the hollow shaft was set as 3 mm. The finite element model after mesh generation is shown in Figure 4. The constraint method and load application method are described in the previous geometric model, as shown in Figure 4. The "H-output" command is set to T=10 times.

4. SIMULATION CALCULATION AND ANALYSIS

According to the experimental needs of students, loading is set up in the software. The applied load direction is the negative direction of Y axis, and the load sizes are 5 kN, 10 kN and 15 kN in turn. The finite element model is simulated on the computer, and the Mises stress nephograms under different parameters is obtained.

4.1. Simulation Results

When the external load was small (5 kN), the Mises stress nephograms of the finite element model is shown in Figure 5.

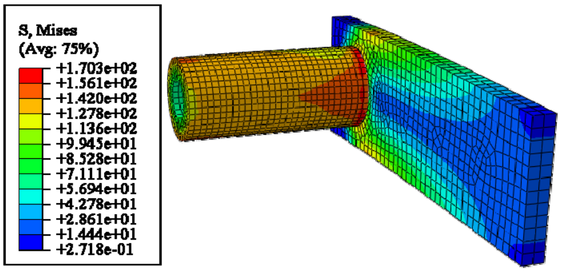


Figure 5: Mises stress nephograms of the finite element model: load *F*=5 kN.

It can be seen from Figure 5 that the overall deformation of the model is not obvious and the Mises stress is not significant. However, stress concentration appeared in the model, and its position is at the junction of hollow shaft and shank. The maximum Mises stress of the whole model is 170.3 MPa.

Similarly, Mises stress nephograms of the finite element model with loads of 10 kN and 15 kN are obtained, as shown in Figure 6 and Figure 7.

As can be seen from Figure 6, the overall deformation of the model is not obvious. However, compared with Figure 5, the Mises stress of the model has been significantly increased. The maximum Mises stress of the finite element model is 340.6 MPa. The stress concentration is still located at the junction of hollow shaft and stalk.

Figure 7 shows the Mises stress nephograms of the finite element model with an external load of 15 kN. It can be seen from Figure 7 that the stress of the finite element model is already very high at this time. In particular, the stress on the surface of hollow shaft has exceeded 400 MPa in all parts. According to the material properties set above, the surface of the shaft has begun to undergo irreversible plastic deformation. Generally speaking, the required stress in steel parts does not exceed 400 MPa, so it can be preliminarily concluded that the applied force is already overloaded.

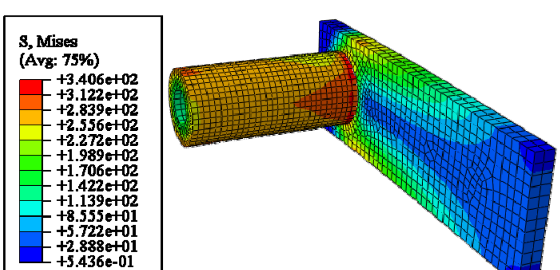


Figure 6: Mises stress nephograms of the finite element model: load *F*=10 kN.

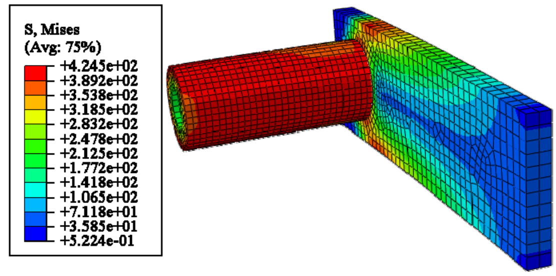


Figure 7: Mises stress nephograms of the finite element model: load *F*=15 kN.

In order to analyze the deformation of the parts more clearly, the finite element model with external load of 15 kN was observed along the negative direction of Z-axis. The observation result is shown in Figure 8.

It can be clearly seen from Figure 8 that the position of the shank has changed significantly. The closer to the hollow axis, the greater the stress. But the two corners of the shank near the hollow shaft, the stress is very small. This is because these regions do not transfer stress/strain. In addition, the stress distribution on the hollow shaft section shows the law that the farther away from the axis, the greater the stress. The stress value of the inner surface of the hollow shaft is 172 MPa, while the stress value of the outer surface is 420 MPa. This law is consistent with the formula of polar moment of inertia in the course of Material Mechanics. In short, the hollow shaft has undergone obvious deformation under the combined action of bending and torsion. In order to study the bending deformation behavior of hollow shaft, the distribution of stress (S33) in z-axis direction was observed. Under the action of 15kn external load, the S33 stress nephograms of the finite element model is shown in Figure 9. As can be seen from Figure 9, the stress distribution of the hollow shaft at the place where the constraint is applied is obviously different. The upper part bears tensile stress while the lower part bears compressive stress. This distribution law is consistent with the law of single bending action. Based on the analysis of Figure 8 and Figure 9, it can be seen that the points of maximum stress are at the top and bottom of the left side of the hollow shaft.

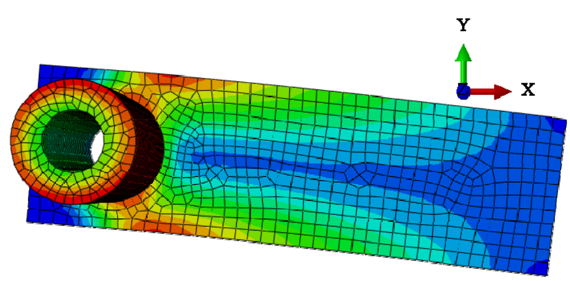


Figure 8: Observation in the negative direction of Z-axis.

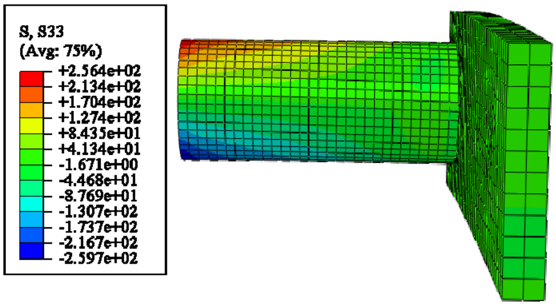


Figure 9: S33 stress nephograms of the finite element model: load F=15 kN.

In order to better study the bending deformation, some nodes of the hollow shaft were marked. As shown in Figure 10, the node of the hollow axis (as marked by the green wireframe in the figure) is named Node 1. Name special nodes every 1 node along the axis. As indicated by the blue wireframe in Figure 10, it is Node 2. Along the axis of the hollow axis, there are Node 3, Node 4 in turn, and the last special node is named Node 14 (marked by the yellow wireframe in the figure).

The Mises stress data of these special 14 nodes were invoked in the database obtained from the simulation calculation, and the research work was carried out. Under 5 kN external load, the Mises stress values of the marked special 14 nodes are counted, as shown in Figure 11.

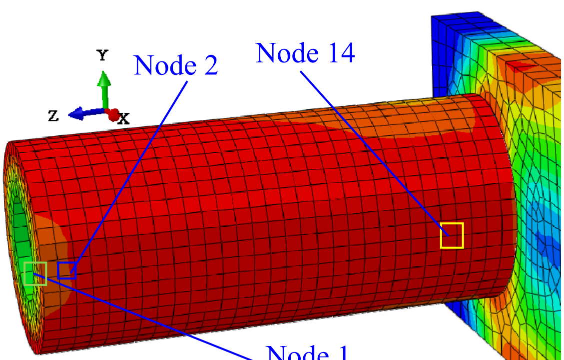


Figure 10: Several nodes of the model were marked.

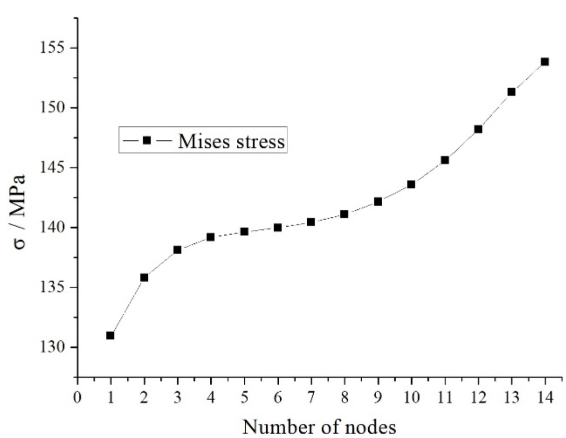


Figure 11: Stress distribution statistics of marked nodes: F=5 kN.

As can be seen from Figure 11, the Mises stress gradually increases with the increase of node label. The increasing trend shows the characteristics of intense in the initial stage, moderate in the middle stage and intense again in the later stage. The Mises stress of Node 14 is the largest, and its value is 153.8 MPa.

Under 10 kN external load, the Mises stress values of the marked special 14 nodes are counted, as shown in Figure 12. As can be seen from Figure 12, the Mises stress gradually increases with the increase of node label. Similarly, the increasing trend shows the characteristics of intense in the initial stage, moderate in the middle stage and intense again in the later stage. The Mises stress of Node 14 is the largest, and its value is 307.7 MPa. Under 15 kN external load, the Mises stress values of the marked special 14 nodes are counted, as shown in Figure 13. As can be seen from Figure 13, the Mises stress gradually increases with the increase of node label. The change trend shows a law of obvious increase in the initial stage and basically unchanged in the middle and later stages. The Mises stress of Node 13 is the largest, and its value is 419.1 MPa. Excessive external load leads to plastic deformation on almost the whole surface of hollow shaft.

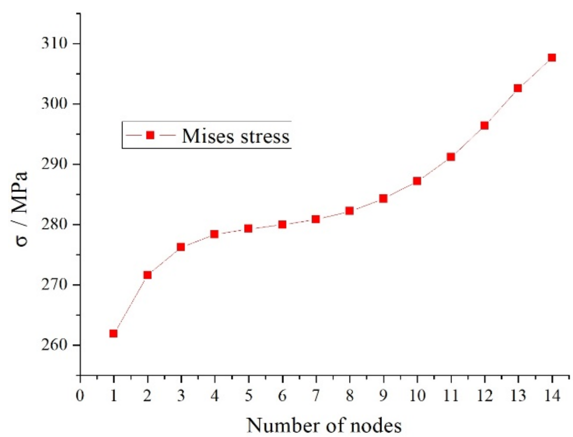


Figure 12: Stress distribution statistics of marked nodes: F=10 kN.

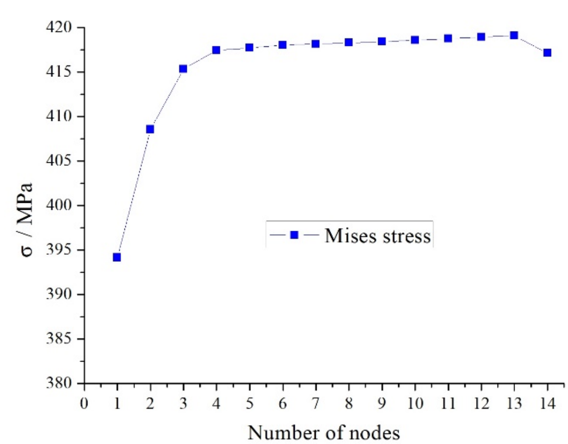


Figure 13: Stress distribution statistics of marked nodes: F=15 kN.

4.2. Results Analysis

A large amount of data and the Mises stress nephogram were obtained from the finite element simulation calculation. The data from these test reports supports the design and optimization of the students' entries and accelerates the progress of the entries. During the whole problem-solving process, the students have done a lot of work, and their abilities in all aspects have also been exercised. The research team conducted a questionnaire, and the survey questions are as follows:

Q1: Does the finite element modeling and simulation technology solve the problem?

Q2: has your analysis ability been improved?

Q3: has your data analysis ability been improved?

Q4: has your written expression ability been improved?

The six students who participated in the competition answered "yes" to the above four questions, as shown in Figure 14.

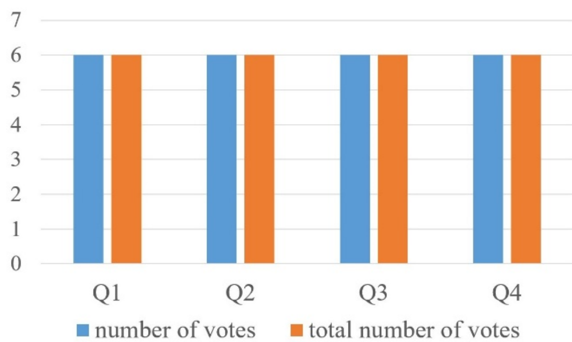


Figure 14: A questionnaire about simulation.

In addition to solving the design problem of the entries in the students' skills competition, the modeling work also expands the students' knowledge vision. The students learned about the basic theory of finite element and the basic principles of ABAQUS software. Two students in the participating team are very interested in simulation technology and ABAQUS software. The two students made it clear that they would take time to learn ABAQUS software in the future. Students are interested in learning and willing to take the initiative to learn, which is what all teachers want to see. From this point of view alone, the research team's efforts are valuable.

In conclusion, the problems faced by the entries are solved through the simulation technology. In the process of solving problems, the students' various abilities have been exercised and improved.

5. CONCLUSION

In the design and production of the entries, the students encountered the problem of being unable to carry out mechanical test. The research team proposed a solution to modeling and simulation. With the joint efforts of the participating team members and the research team, the problem was solved, and the main conclusions of this paper are as follows:

(1) The modeling and simulation technology can be used for solving mechanical testing problems in technical skills competitions.

(2) In the process of using the simulation technology to solve problems, the students undertook a lot of work. The work helped the students to improve their problem analysis ability, data analysis ability and written expression ability.

(3) The simulation technology expands students' knowledge and stimulate some students' desire to learn.

Vocational colleges should pay more attention to the modeling and simulation technology, and the technology should be applied in more fields.

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