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Design and Development of Small Modular Courses for "Education-Training Integration" in Vocational Colleges: A Case Study

Zhixin Feng[1], Meiqin Liang[2]*

[1]School of Automotive Engineering, Beijing Polytechnic, Beijing 100176, China
[2]College of Automation Engineering, Beijing Polytechnic, Beijing 100176, China

***Corresponding author:** Meiqin Liang, liangmeiqin@bpi.edu.cn

Abstract: Vocational education plays a vital role in the development of skilled technical professionals and the advancement of the economy. However, the emphasis on campus education often neglects the importance of external training, hindering the overall development of vocational education. This study aims to address this issue by exploring the design and development of small modular courses that integrate training and education in vocational colleges, focusing on the mechanics course as a case study. The research methods employed in this study include an in-depth analysis of enterprise training needs, the development of digital teaching resources utilizing the finite element method (FEM), and the implementation of a small modular course integrating education and training. The data analysis reveals positive outcomes in terms of learners' comprehension and engagement with complex mechanics formulas through the use of stress nephograms and other digital resources. This research provides a new perspective on curriculum design and offers insights into the integration of training and education in vocational colleges. The findings underscore the significance of incorporating innovative teaching methodologies and digital resources in enhancing the quality and relevance of vocational education, ultimately contributing to the cultivation of skilled professionals and the growth of the vocational education sector.

Keywords: Education-training integration; Small modular courses; Vocational colleges; Training; Finite element method

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1. Introduction

Vocational education plays a vital role in fostering highly skilled technical professionals and driving economic development. While vocational colleges have excelled in providing campus education, they have overlooked the importance of external training. External training is crucial for enhancing employees' skills and promoting the integration of industry, academia, and research. Vocational colleges must recognize the significance of external training and achieve coordinated development between campus education and external training. To implement effective external training, vocational colleges must consider learners' backgrounds, including their learning foundations, work experiences, and career development needs [1]. The traditional approach of replicating campus education's content and teaching methods is insufficient for the development expectations of adult learners and enterprises. Vocational colleges must innovate teaching models and methods that combine theory and practice, improving the targeted and practical effectiveness of the training. Strengthening communication and collaboration with enterprises to develop training plans aligned with their needs is essential [2].

Mechanics courses in vocational education often focus on mathematical knowledge, such as calculus, which poses challenges for enterprise training [3]. This study addresses this issue by optimizing the existing campus teaching curriculum and developing digital teaching resources utilizing the finite element method (FEM) with stress nephograms as examples. These resources provide learners with convenient and effective ways to understand complex mechanics formulas. A small modular course for education-training integration is established, and teaching experiments and evaluations validate the scientificity of the proposed approach.

2. Research methods

2.1. Research logic

In this study, the "polar moment of inertia" in the mechanics course was selected as the core teaching content, and the research was carried out through the following logically rigorous steps. Firstly, we constructed the corresponding geometric model and clarified the key geometric dimensions and material parameters. Subsequently, a three-dimensional model of solid shaft torsion was established using the FEM, and numerical calculations were performed on a high-performance server to obtain von Mises stress nephograms and displacement nephograms. Based on these digital teaching resources, we then carried out an innovative redesign of the original curriculum to better meet the learning needs of enterprise employees. Following that, teaching experiments were organized to apply the optimized curriculum to practical teaching. Lastly, the effectiveness and practicality of the teaching method were verified through the collection and analysis of teaching evaluation data. The entire research process is logically clear, ensuring the accuracy and reliability of the research results.

2.2. Geometric model

We designed a teaching case on solid shaft torsion to help students understand the concept and formula of the polar moment of inertia in the mechanics course through the deformation caused by shaft torsion. The geometric diagram of the case is shown in **Figure 1**, and the coordinates of key points are listed in **Table 1**. The material of the shaft is aluminum alloy. The right part of the shaft has a smaller outer diameter, while the left part has a larger outer diameter. The left side of the shaft is fixed. A torque of 100 Nm is applied to the right end face of the shaft along the axis.

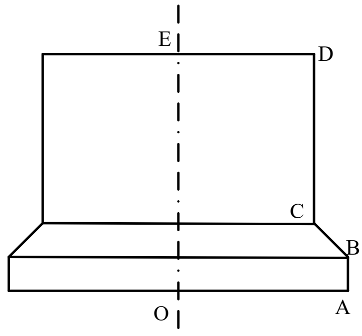

Figure 1. Geometric model diagram

Table 1. Coordinates of key points in the geometric model

Symbol	Coordinate	Symbol	Coordinate
O	(0, 0)	C	(20, 10)
A	(25, 0)	D	(20, 30)
B	(25, 5)	E	(0, 30)

2.3. Modeling and simulation calculation

Based on the data from **Figure 1** and **Table 1**, we established a finite element model. In the "meshing" command, we selected "Tet" as the element shape and "Media-axis" as the type. The element type "C3D10" was chosen. The model was locally refined, and the meshed model is shown in **Figure 2**. We performed simulation calculations on a server and obtained digital resources represented by stress nephograms. In finite element software, colors are used to indicate the magnitude of physical quantities. For example, for stress, the redder areas represent higher stress values, while the bluer areas represent lower stress values. This intuitive representation method is easier for students to understand than the traditional mathematical derivation based on mechanical formulas. **Figure 3** shows the simulated stress nephogram.

From **Figure 3**, it can be observed that the stress distribution exhibits obvious axial symmetry. Due to the smaller amount of metal used to withstand the torque, the stress on the shaft with a smaller outer diameter is significantly higher than that on the shaft with a larger outer diameter. Observing the shaft with a smaller outer diameter, it can be seen that the stress increases as the distance from the axis increases. The maximum von Mises stress occurs on the outer surface of the shaft with a smaller outer diameter. The maximum stress for the case is 16.23 MPa, occurring at the contact position between the shaft with a larger outer diameter and the shaft with a smaller outer diameter, which is a typical Saint-Venant's principle phenomenon. **Figure 4** shows the simulated displacement nephogram. From **Figure 4**, it can be observed that the displacement/deformation increases as the position on the shaft with a larger outer diameter moves away from the bottom surface. This is because the torque is applied to the right end face of the shaft with a smaller outer diameter, while the left end face of the shaft with a larger outer diameter is fixed. The maximum displacement/deformation occurs at the edge of the right end face of the smaller shaft and has a value of 0.007452 mm. In our original curriculum framework, we integrated the digital resources mentioned earlier. These resources include six von Mises stress nephograms, two displacement nephograms, and one animation.

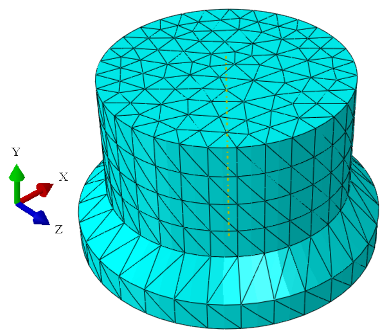

Figure 2. Finite element model diagram after mesh generation

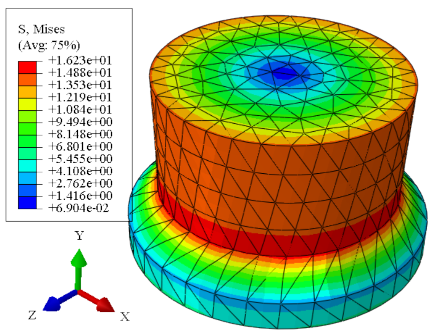

Figure 3. Von Mises stress nephogram after simulation

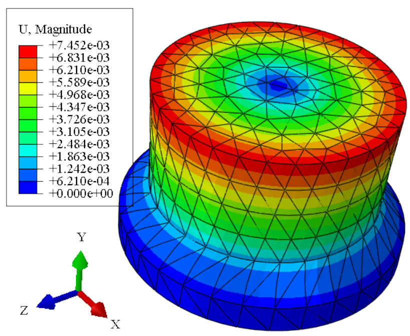

Figure 4. Finite element model diagram after mesh generation

2.4. Evaluation method

We employed a questionnaire survey to assess the quality of teaching. The survey questionnaire consisted of four questions, labeled Q1–Q4, as shown in **Table 2**. Each question had four options: A (Strongly agree), B (Agree), C (Disagree), and D (Abstain). The agree rate (A_r) was calculated by summing the votes for options A and B and dividing it by the total number of responses. We used A_r to measure the students' acceptance of this study. A total of 60 students from enterprises participated in this teaching experiment and completed our survey questionnaire.

Table 2. Question settings for the questionnaire

Mark	Questions to investigate
Q1	Do you find the teaching content of the "polar moment of inertia" in the mechanics course clear and easy to understand in this training session?
Q2	Do you feel that the digital teaching resources assisted by FEM, such as von Mises stress nephograms, displacement nephograms, etc., have improved your learning efficiency and interest?
Q3	How do you perceive the practicality and adaptability of the redesigned course in practical application?
Q4	Overall, are you satisfied with the teaching effectiveness of this course?

3. Result and discussion

3.1. Data analysis

We compiled the questionnaires from the participants and obtained the statistical results. For Q1, a high A_r of 93.33% indicates that the teaching content of the "polar moment of inertia" in the mechanics course was perceived as clear and easy to understand by the participants. This demonstrates the effectiveness of the teaching approach. Regarding Q2, with A_r = 85.00%, it can be inferred that the utilization of digital teaching resources, such as von Mises stress nephograms and displacement nephograms through FEM, has positively impacted the participants' learning efficiency and generated interest. In relation to Q3, the A_r of 88.33% suggests that the redesigned course exhibited practicality and adaptability in practical application, indicating its relevance to real-world scenarios and meeting the needs of the learners. Regarding Q4, the high A_r (91.67%) indicates overall satisfaction with the teaching effectiveness of the course. This suggests that the optimized curriculum, supported by digital resources, successfully enhanced the learning experience for the participants.

3.2. Discussion

Firstly, external training is equally important as campus education in vocational colleges, as it effectively complements and enhances the content and teaching methods of campus education courses [4]. Secondly, personalized and targeted education has been extensively studied and recognized as essential in both external training and campus education. It is crucial for both forms of education to consider learners' backgrounds and abilities to ensure effective and tailored instruction [5]. Lastly, the development of digital teaching resources aligns with the important trend of technological advancement in vocational education. The utilization of digitalized materials offers flexibility, accessibility, and interactivity, enhancing the overall learning experience [6,7]. By integrating external training with campus education, vocational colleges can create a comprehensive educational ecosystem that caters to diverse learner needs and promotes lifelong learning.

4. Conclusion

The successful integration of digital teaching resources, such as von Mises stress nephograms, displacement nephograms, and animations, supported by the utilization of the FEM, has demonstrated its effectiveness in enhancing the mechanics course. The evaluation results obtained through the questionnaire survey indicate that this innovative approach to curriculum design has resulted in clear and comprehensible teaching content, improved learning efficiency and interest, and practical applicability in real-world scenarios. The participants' high satisfaction with the teaching effectiveness further supports the value of this integrated approach. These findings not only contribute to the field of engineering education but also provide novel insights for vocational colleges in their external training programs.

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Author contributions

Conceptualization: Zhixin Feng
Formal analysis: Meiqin Liang
Writing – original draft: Zhixin Feng
Writing – review & editing: Meiqin Liang

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