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Innovative Teaching Model and Practice of "Steel Structure Design" Based on the Strategy of "Vertically and Horizontally"

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Abstract: With the rise of the steel structure industry and the requirements of course ideology and political construction as well as innovation and entrepreneurship education, an online teaching course was created with the help of Internet technology to promote the reform of the traditional classroom teaching model of "Steel Structure Design." The teaching team innovatively proposed the "Vertically and Horizontally, Spiral Improvement" teaching model and a transparent "Three - time Evaluation and Feedback" mechanism, and gradually carried out teaching practice. By comparing and analyzing the effects of four teaching models, the superiority of this innovative teaching model and evaluation mechanism is preliminarily demonstrated, which has a certain exemplary effect.

Keywords: teaching research, steel structure design, vertically and horizontally, three - time evaluation and feedback mechanism, Chaoxing learning platform

1. Introduction

In 2020, the Several Opinions on Accelerating the Development of New - type Construction Industrialization vigorously promoted the development of steel structure buildings as well as the comprehensive development of related key technologies and industries, and supported colleges and universities in connecting with the new demands of the construction industry and innovating talent - training modes to provide professional talent guarantees。In 2021, the General Office of the State Council's Guiding Opinions on Further Supporting College Students' Innovation and Entrepreneurship required that "Innovation and entrepreneurship education should run through the whole process of talent training." Meanwhile, the development of online courses has opened up a new model for a large number of learners to acquire knowledge and improve their skills. The online - based teaching of quality teaching resources and classroom teaching is a challenge to teachers' ability to convey professional knowledge and will also promote the optimization of course teaching design (Wang, 2015).

In order to cultivate steel structure professionals at different levels, professional teachers from various colleges and universities fully use a variety of teaching methods to train steel structure design talents. The introduction of experimental teaching and simulation practice teaching integrates abstract theoretical knowledge with specific experiments, effectively improving the teaching effect of steel structure design (An et al., 2019; Jia & Liu, 2010). Scientific research feedback and bilingual teaching are also effective means of stimulating students' interest in learning and expanding their knowledge with an international vision (Zhao & Zhao, 2018; Jia et al., 2009); Introducing steel structure - related design software, research results, typical project construction drawings and site observation into

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course teaching, and combining them with steel structure course design, not only improves students' learning initiative, but also improves their engineering practice ability (Li & Tian, 2011; Jia et al., 2014). With the rise of online courses, many teachers committed to promoting the development of steel structures have followed the trend of the times, actively developed online courses, explored new ideas for teaching design, and achieved some initial results. The professional certification implemented by the Ministry of Education has implanted the modern educational concept of result - oriented into the teaching system, determined the training goals, and assessed the teaching effect, which has greatly promoted the innovation of steel structure design teaching model (Shao et al., 2020).

At the second national education conference in September 2024, General Secretary Xi proposed the "six capabilities" that an education power must possess. The "ideological and political leadership" in the first place fully shows the political nature of education. Therefore, the teaching practice of course - based ideological and political education not only involves the process of individual political socialization, but also affects the efficiency of national ideological and political construction (Tang & Guan, 2025)。Under the background of the reform of higher education in the new era, it is necessary to deconstruct and reshape the relevant course content and integrate ideological and political elements to achieve the organic unity of knowledge conveyance, ability - building and value - leading (Zhao et al., 2025)。

Combining the requirements of course - based ideological and political education and innovation and entrepreneurship education, our teaching team, based on the university's talent - training principle of "student - oriented, morality - first, ability - oriented, and comprehensive - development," has carried out the innovative practice of the "Vertically and Horizontally, Spiral Improvement" teaching model and the "transparent three - time evaluation and feedback" mechanism of the "Steel Structure Design" course on the basis of using information technology to improve the course - teaching quality, and practiced the "value - shaping, ability - building, and knowledge - conveying" three - in - one talent - training model.

2. Construction of the Online Teaching Platform for "Steel Structure Design"

The content of the online platform for "Steel Structure Design" covers four types of structures: the calculation theory, design principles and specification clauses of light - type portal frame structure, medium - and heavy - type workshop structure design, long - span roof structure and multi - and high - rise building structure, each of which has its own characteristics and forms its own system. In 2018, the steel structure teaching team began to build the online platform for the "Steel Structure Design" course on the Chaoxing Fanya Network Teaching Platform of our university, with relatively rich resources, including the teaching outline and lesson plans, four chapters of relevant teaching resources: 98 online teaching videos, 840 exercises, as well as videos and design materials for extended learning. At the same time, in combination with the content of each module course, ideological and political elements were explored from aspects such as national sentiment, scientific and technological innovation, craftsman spirit and engineering ethics, and 26 short video stories lasting 4 - 9 minutes were made with Xunfei ZhiZuo digital people. The main materials of each module are shown in Table 1.

Table 1 Summary of Online Resources for "Steel Structure Design"

Chapter	Course Video / Segment	Key Content of the Course	Ideological Video/ Segment	Key Content of Ideological Education
Light-weight Portal Frame Structure	28	Structural Layout; Design of Purlins, Rigid Frames and Bracings	6	No. 9 Blast Furnace; National Stadium; Portal Frame Collapse Cases; Formulation of Codes/Standards, etc.
Medium and Heavy-duty Workshop Structures	26	Structural Layout and Calculation Principles; Design of Steel Roof Trusses and Crane Girders	6	President Xi Jinping Inspects Ma Steel; Shen Fei, a Master Craftsman of a Great Nation; the Collapse Accident of the Quebec Bridge, etc.
Long-span Roof Structure	16	Structural Forms; Grid Structure; Latticed Shell Structure; Key Calculation Points for Spatial Grid and Suspension Structures; Cable Structure	8	Lusail Stadium; Daxing International Airport; FAST and Nan Rendong; I.M. Pei and the Louvre Pyramid; Grid Structure Collapse Cases, etc.
Multi-story and High-rise Building Structures	28	Structural Layout; Design of Composite Floors, Columns and Braces; Structural Analysis of Multi-story and High-rise Buildings; Structural Design	6	Development and Innovation of Steel Structures in China; Guangshang Center; CITIC Tower; Shenzhen Grand Central Plaza; Citicorp Center Crisis, etc.

Students initially understand the main tasks, objectives, and content of each lesson of the course through teaching documents such as the teaching outline and lesson plans. They then study the course content and knowledge points in detail through videos, and finally complete after - class assignments or tests. The question bank used for assignments, tests or examinations has a variety of question types and covers a wide range of knowledge points. Questions are classified according to their levels of difficulty, which facilitates the consolidation of key and difficult knowledge and is conducive to improving students' ability to apply knowledge flexibly to solve practical problems. Meanwhile, by using the online ideological and political short videos on the platform, assigning group tasks, and encouraging students to look up relevant materials to obtain richer ideological and political elements and participate in topic discussions, students can improve their humanistic and spiritual qualities and realize value - leading.

3. Innovative Teaching Model and Evaluation Mechanism

3.1. "Vertically and Horizontally, Spiral Improvement" teaching model

The course "Steel Structure Design" contains a large number of knowledge points and is highly difficult, making it hard for students to master all the content in a short time. Based on the characteristics of the main content of the course, and targeting civil engineering students and technicians engaged in the civil engineering field, the teaching team, combining the engineering design background of the "dual - type" teachers of this team, proposed the innovative "Vertically and Horizontally, Spiral Improvement" teaching model, which takes the four major structural knowledge systems as the vertical main line, and integrates the hidden ideological and political education horizontally into the explicit knowledge education to achieve the course objectives.

In this model, "Vertical Integration" refers to the vertical guidance of teaching content through the method of "example - based introduction → breaking

down the whole into parts → integrating parts into the whole → integrating into practice." This helps students to clarify their thinking, grasp the basic design theory and methods of structures, complete course - training projects, and on this basis, participate in subject competitions to improve their comprehensive practical abilities.

(1) Example - based Introduction: By using the various structural videos on the "Xueyin Online" platform, students are led to "enter" real structures to understand application scenarios, initially master relevant professional terms, and learn the composition and layout principles of different types of structures. The "topic discussion" function of Chaoxing Learning is used to guide students to participate in discussions on the characteristics of various structural layouts.

(2) Breaking Down the Whole into Parts: In the classroom, students are inspired to decompose the overall structure into main and auxiliary components according to the primary and secondary force - bearing aspects. The mechanical model, calculation theory, and verification methods of key components are explained in detail. Using the question bank, in - class mini - tests are conducted during the teaching process to check students' listening effects, and calculation - based assignments are given to assess students' understanding of the design methods of key components.

(3) Integrating Parts into the Whole: In combination with the content of the major assignments of each chapter, "group tasks" are assigned. The "group discussion" function is used to organize students to follow design principles and methods. Through full discussion and collaborative cooperation, students complete the calculation from components to the entire structure to ensure the safety and reliability of structural design.

(4) Integrating into Practice: The design results and construction measures of steel structures are presented in the form of calculation books and engineering drawings. With the help of the online material library, the expression methods in engineering drawings are demonstrated in detail. Students are encouraged to learn from engineering practice. Brainstorming, enumeration, and association methods are used to stimulate students' creative thinking, improve their problem - solving abilities, and enhance their self - confidence.

"Horizontal Connection" refers to the organic integration of short - video stories containing ideological and political elements, online Q & A sessions with design - institute experts, application of design software, and reviews of students' works in subject competitions into every link of course teaching. As the four types of structural forms are unfolded from far to near and from shallow to deep, the innovative development and scientific achievements of China's steel structures are gradually revealed. The red genes intertwined with steel structure knowledge are subtly integrated into students' thinking, thus realizing the "spiral improvement" of spiritual connotation. As Chairman Mao pointed out in "On Contradiction": "Human cognition always proceeds in this cyclical manner. Each cycle may lead to a step - by - step improvement in human cognition, constantly deepening our understanding."

3.2 Transparent "Three - time Evaluation and Feedback" mechanism

The teaching team of this course, with the help of the online teaching platform, proposes the "transparent three - time evaluation and feedback" mechanism, which combines teacher evaluation with student peer - evaluation, and opens the grade - checking function to form a transparent formative evaluation mechanism. This not only enables students to manage themselves but also helps teachers to grasp the learning situation. The specific steps are as follows: First, through the "topic discussion" and "group task" functions of Chaoxing Learning, online tasks are assigned. The "first evaluation and feedback" is based on the completion and effectiveness of "video learning" and "pre - class tests." Then, in the classroom, real - time interaction is realized through "selecting people," "in - class tests," and "group reports," which promotes the dissemination of knowledge and the penetration of

ideological and political content. The "second evaluation and feedback" is based on the completion of tasks. Finally, the "assignment" function is used to urge students to consolidate the learning results of key and difficult points, and the "third evaluation and feedback" is carried out.

4. Teaching Practice and Achievements Based on the "Vertically and Horizontally" Model

4.1 Teaching practice of the innovative model

The teaching objective of this course is for students to master the basic forms, layout principles, calculation models of the four types of steel structures, as well as the verification, node design, and construction requirements of key components. Students should also have the ability to initially solve problems in complex engineering design and develop correct values, critical thinking, and innovation capabilities. To achieve this goal, the course team studies the teaching content and difficulties of each class, and carries out teaching practice using the "Vertically and Horizontally" model and the "three - time evaluation and feedback" mechanism. Taking the design of crane beams in Chapter 2 as an example:

Using the ideological and political videos in the online course, such as the General Secretary's inspection of Magang, the industrial heritage No. 9 blast furnace, and the development of crane beams, students are guided to understand the role of crane beams in heavy - industry workshops, realizing the "example - based introduction" and the subtle "horizontal connection" with national sentiment.

The teaching content is divided into three levels of difficulty: easy, medium, and difficult, to achieve "breaking down the whole into parts." Pre - class online course video - learning tasks are assigned, and pre - class tests are conducted on the section classification and load - bearing capacity verification methods of crane beams. Students understand their grasp of the knowledge points based on the test results, realizing the "first evaluation and feedback." Based on the results of the first evaluation, teachers assign discussion topics (other factors affecting the fatigue performance of crane beams) and group tasks (fatigue verification methods of crane beams) related to the key and difficult points of knowledge and related ideological and political content. Students are encouraged to look up cutting - edge hotspots related to the difficult knowledge of crane beams and connect with scientific research.

In the classroom, interactive teaching is carried out in a problem - oriented manner. In the process of solving fragmented problems, students gradually grasp the key and difficult points of crane beam design and fully understand the design principles of crane beams, realizing "integrating parts into the whole." The second evaluation and feedback are realized through in - class tests, group reports, and peer - evaluation. For design difficulties that students are concerned about, actual engineering experience and answers are obtained through communication with design - institute experts, connecting scientific research frontiers and engineering practice.

After class, major design assignments of crane beams are assigned for key and difficult knowledge points to "integrate into practice." This effectively extends classroom learning, consolidates and digests new knowledge. The third evaluation and feedback are realized through assignment grading, scoring, and comments. For knowledge points with poor grasp and key and difficult content, according to the Ebbinghaus forgetting curve, discussions are organized again in the next class to effectively improve memory and problem - solving abilities.
Students are guided to participate in subject competitions to more deeply "integrate" the knowledge related to crane beam design into practice. Brainstorming and divergent thinking are carried out to obtain more solutions and optimize structural design models, cultivating an innovative spirit.

In the teaching design of "Steel Structure Design," the use of the "Vertically and Horizontally" teaching model enables students' knowledge structure to spiral upward. Students also understand the ideological and spiritual connotations contained in the professional knowledge system. The transparent "three - time evaluation and feedback"

mechanism makes students and groups clear about their knowledge - grasp of each class and their regular grades, stimulating students' learning initiative and team - cooperation awareness.

4.2 Reform achievements of the innovative teaching model

Through the implementation of the "Vertically and Horizontally" teaching and the "three - time evaluation and feedback," students' learning enthusiasm and grades have been significantly improved. To demonstrate the promoting effect of this innovative teaching model on course - teaching effectiveness, the grades of various classes over the past four years have been statistically analyzed. The comparison chart of pass rates, good rates, and excellent rates of grades under four teaching modes is shown in Figure 1. Mode 1 refers to offline teaching in small classes; Mode 2 refers to hybrid online - plus - offline teaching in small classes; Modes 3 and 4 refer to the "Vertically and Horizontally + three - time evaluation and feedback" innovative teaching in small and large classes, respectively.

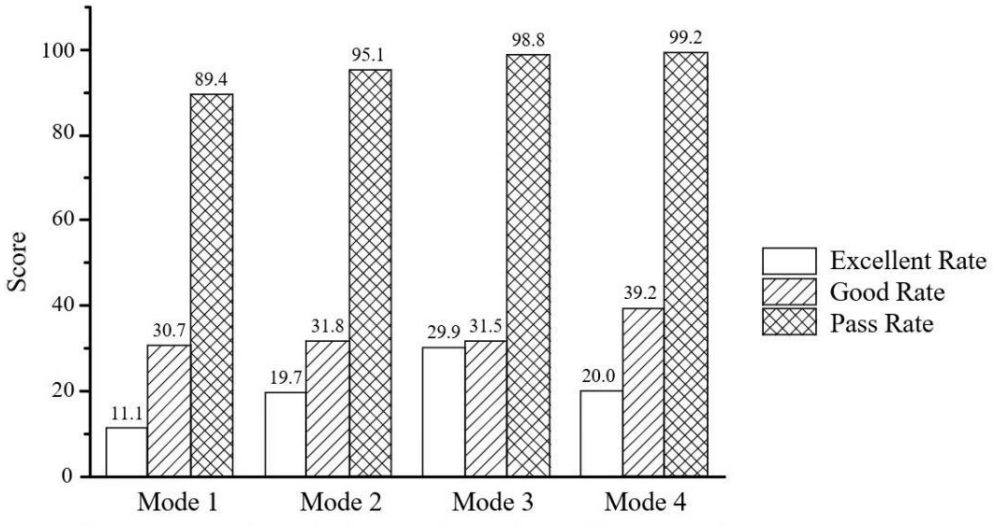

Figure 1 Comparison of Class Grades Under 4 Different Modes

From the figure, it can be seen that the teaching effect of this innovative teaching model is significantly improved compared with offline and blended teaching; however, the excellent rate of large - class teaching is slightly lower than that of small - class teaching. The teaching effect of the traditional offline teaching model is worse than that of the blended online - and - offline teaching model. Therefore, with the development of Internet technology, the traditional teaching model is in urgent need of reform.

At present, teachers in the teaching team adopt the innovative "Vertically and Horizontally, Spiral Improvement" teaching model in the teaching process, give full play to the teaching functions of the online platform, create a good learning and communication environment for students, and also enable students to understand the development process and frontier of China's steel structure, analyze engineering ethics issues in failure cases, and learn the innovative dedication and craftsman spirit of model figures through ideological and political content, further improving the effect of talent - training. Meanwhile, the "transparent three - time evaluation and feedback" mechanism is adopted. The functions of the online teaching platform, such as video learning, topic discussion, group tasks, assignments, and chapter tests, are used to realize online assessment. Offline assessment is carried out through group reports, in - class tests, and features such as quick-response quizzes have formed an assessment system that bridges online and offline learning, effectively stimulating students' enthusiasm for learning.

In addition, the reform of the teaching model has not only achieved good results in the teaching of this course, but also attracted students to actively participate in subject competitions and "College Students' Innovation and Entrepreneurship Training Program" projects, actively meet various challenges, further cultivate students' innovative thinking and practical abilities, and achieve the subtle and silent talent - training effect, realizing the "double spiral improvement" of knowledge and ideological and political education. The innovative teaching model and assessment mechanism have been recognized by students and promoted in teaching experience - sharing meetings and demonstration observation classes. Meanwhile, the course provides an online learning channel for professionals engaged in steel structure design, construction and management through "Xueyin Online," with a cumulative number of learners reaching 2.62 million, further expanding the course's radiation range and influence.

5. Conclusion

In the context of contemporary higher education reform, the teaching team has established the online course of "Steel Structure Design" on the Chaoxing Fanya Network Platform, produced a wealth of course - based ideological and political short videos related to the course content, and initially carried out teaching practice. By comparing the grades of students under four teaching models, the "Vertically and Horizontally" innovative teaching model can achieve logical connection of knowledge before, in and after class, as well as the hidden integration of ideological and political elements, reflecting the scientific talent - training concept of student - centered and teacher - led. The "transparent three - time evaluation and feedback" mechanism helps to cultivate students' autonomous learning ability. In addition, the construction of online platform courses needs to unremittingly supplement the cutting - edge knowledge of the discipline and ideological and political elements, expand the width of the course, explore the depth of knowledge, and realize the demonstrative goal of online teaching model of "Steel Structure Design."

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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References

An, Y., et al. (2019). Practice and research on experimental teaching of steel structure design course. *University Education, 2019*(11), 54–56.

Jia, D., & Liu, W. (2010). Preliminary exploration of simulation practice teaching of steel structures. *Supplement to Steel Structures, 25*(141), 909–912.

Jia, D., et al. (2009). Preliminary practice of audiovisual bilingual teaching in steel structure course. *Journal of Anhui University of Technology, 26*(2), 133–134.

Jia, D., et al. (2014). Reform of teaching model for steel structure course design. *Supplement to Steel Structures, 29*(193), 831–834.

Li, F., & Tian, C. (2011). Discussion on practical teaching methods for steel structure design course. *Higher Architectural Education, 20*(1), 135–137.

Shao, J., et al. (2020). Teaching reform and practice of "Steel Structure Design" course under the background of professional accreditation. *Education and Teaching Forum, 3*(12), 136–137.

Tang, W., & Guan, X. (2025). The logic, difficulties, and strategies of embedding emotional sociology into ideological and political courses: An analytical framework based on the "emotion–society" double helix structure. *Educational Theory and Practice, 45*(27), 43–49. https://doi.org/CNKI:SUN:JYLL.0.2025-27-008

Wang, Q. (2015). Universities facing MOOCs: Opportunities and challenges. *China Higher Education, 2015*(24), 7–8.

Zhao, B., & Zhao, D. (2018). Teaching reform of steel structure design course based on engineering-oriented talent cultivation. *Higher Architectural Education, 27*(2), 72–75.

Zhao, J., Zhang, Y., Zhang, L., et al. (2025). Integration of science education and ideological education: Teaching construction and educational practice exploration of "Cell Biology" undergraduate course at the University of Chinese Academy of Sciences. *Progress in Biochemistry and Biophysics,* 1–9. https://link.cnki.net/urlid/11.2161.Q.20250924.1712.008

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