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# Table of Content

<b>THE EFFICACY OF MODERATE-INTENSITY TRAINING FOR OVERWEIGHT AND OBESE UNIVERSITY MALE STUDENTS</b> Cheng Ma*, DaXi Mou	1-4
<b>THE IMPLEMENTATION OF THE "DOUBLE REDUCTION" POLICY IN CHINESE PRIMARY AND SECONDARY SCHOOLS: AN ANALYSIS OF THE POLICY FRAMEWORK AND IMPLEMENTATION STRATEGY</b> ShuShu Tian*, JiaHui Yuan	5-14
<b>ENHANCING PROFESSIONAL ENGLISH SKILLS IN SPORTS PROGRAMS: APPLICATION AND CHALLENGES OF INTERACTIVE TEACHING METHODS</b> ZiLin Cheng, Tao Luo*	15-20
<b>RESEARCH ON SUPPLIER SELECTION STRATEGY BASED ON AHP</b> XueQing Guo*, Qiong He, Shuang Yu	21-27
<b>DISCUSSION ON THE MECHANISM OF TCM PREVENTION AND TREATMENT OF "INFLAMMATION-CANCER" TRANSFORMATION</b> MengYao Hu, JingCan Zhuang, XingYu Shao, XinYu Ren, Yu Chen, YuMei Jiao, Lei Liu*	28-30
<b>RESEARCH AND PRACTICE ON THE CONSTRUCTION OF A VIRTUAL SIMULATION TRAINING PLATFORM FOR INTELLIGENT MANUFACTURING</b> YanQiao Ji	31-35
<b>REVERSE MEASUREMENT AND MODELING OF MUDGUARD PROFILE BASED ON LASER SCANNING</b> YanQiao Ji	36-42
<b>RESEARCH ON THE LEGAL GUARANTEE FOR THE PROTECTION OF RURAL ECOLOGICAL ENVIRONMENT AND RURAL ECONOMIC DEVELOPMENT IN CHINA UNDER THE BACKGROUND OF RURAL REVITALIZATION - FROM THE PERSPECTIVE OF LAND DEVELOPMENT AND INDUSTRIAL ADVANCEMENT</b> Yi Xu	43-51
<b>DESIGN AND PRACTICE OF TPRS INTERNATIONAL CHINESE TEACHING MODEL FROM THE PERSPECTIVE OF THE CULTIVATION OF HIGHER-ORDER THINKING SKILLS</b> Qing Tang	52-56
<b>UNIFORM RU NANOPARTICLES WITH MGO SUPPORTED ON BETA ZEOLITE FOR EFFICIENT HYDROGEN GENERATION FROM AMMONIA BORANE HYDROLYSIS</b> YanRan Feng, Feng Wang*	57-61



# THE EFFICACY OF MODERATE-INTENSITY TRAINING FOR OVERWEIGHT AND OBESE UNIVERSITY MALE STUDENTS

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**Abstract: Objective:** The purpose of this study was to examine the effectiveness of an eight-week moderate-intensity continuous training (MICT) intervention on body composition, cardiovascular fitness, and lower extremity (LE) muscle strength in overweight and obese young men. **Methods:** A total of fifty participants completed a supervised 8-week MICT program, which was conducted three times per week, with each training session consisting of 33-minute jogging or brisk walking at 65%-75% of their maximum heart rate (HR<sub>max</sub>), a 10-minute warm-up, and a 5-minute cool-down. Body composition, the Cooper 12-minute run test (12CR), and the 30-second Chair Stand Test (30CST) were assessed before and after the intervention. **Results:** Following the intervention, participants showed significant reductions in body mass, BMI, waist circumference (WC), and waist-to-hip ratio (WHR) ( $p < 0.001$ ). Additionally, there were significant improvements in both aerobic capacity, as measured by the Cooper 12-minute run distance ( $p < 0.001$ ), and functional LE muscle strength, as measured by the 30CST ( $p = 0.002$ ). **Conclusion:** The eight-week MICT program effectively improved body composition, cardiovascular fitness, and functional LE muscle strength in overweight and obese young men. These findings support the potential of MICT as a viable exercise strategy for weight management and health improvement in university settings.

**Keywords:** Exercise training; Weight loss; Physical fitness; Young adult; 30-second Chair Stand Tests

## 1 INTRODUCTION

The global prevalence of obesity among young adults has risen rapidly in recent years, becoming a serious public health challenge. Obesity not only significantly increases the risk of chronic diseases such as cardiovascular disease, type 2 diabetes, and metabolic syndrome, but also has detrimental impacts on their psychological well-being, social life, and future quality of life [1,2]. A previous study has shown that obesity during young adulthood often continues into later life, further exacerbating the incidence rates of chronic diseases and mortality[3]. Therefore, Efficient interventions for preventing obesity and enhancing long-term health outcomes are essential in this pivotal life stage.

Moderate-intensity continuous training (MICT) not only improves adipose tissue metabolism but also boosts aerobic capacity by improving oxygen utilization efficiency[4,5]. MICT has been proven to be a more sustainable exercise modality, especially for those who are overweight and obese, as it is suitable for maintaining long-term adherence. Furthermore, apart from its cardiovascular benefit, MICT also has a positive effect on muscle fitness.[6]. Enhanced LE muscle strength can improve mobility and help prevent functional impairments caused by obesity, which is critical for obese individuals' quality of life.

Previous studies have confirmed the physical and mental health benefits of MICT for obese populations. Still, its impact on LE functional muscle strength in obese individuals remains unthoroughly explored. This study applies the 30-Second Chair Stand Test (30CST) to measure LE strength, which reflects functional fitness in daily activities among obese individuals. By testing body composition, cardiorespiratory fitness, and muscular fitness, this study aims to investigate the impacts of an eight-week MICT intervention on obese university students to provide effective strategies for weight management programs in university settings.

## 2 MATERIALS AND METHODS

### 2.1 Participants

The participants of this study were overweight and obese male university students recruited from a local university. The inclusion criteria were as follows: 1) age 18-23 years; 2) BMI  $\geq 24$  kg/m<sup>2</sup>; 3) lack of regular physical activity; 4) self-reported consistent weight ( $\pm 2$  kg) throughout the previous three months; and 5) non-smoker. Participants who reported any symptoms identified by the Physical Activity Readiness Questionnaire (PAR-Q) were excluded. Following a thorough comprehension of the study's objectives and requirements, all participants provided written informed consent.

### 2.2 Study Procedure

Following the screening, 50 eligible individuals were enrolled to evaluate the efficacy of eight-week moderate-intensity continuous training (MICT) on weight loss and fitness parameters in overweight and obese university students. Participants engaged in three supervised MICT sessions per week, each session consisting of a standardized 33-minute

jogging or brisk walking exercise at 65%–75% of their maximum heart rate (HRmax), which was monitored by Polar Team Pro heart rate monitors and the Rate of Perceived Exertion (RPE) scale to ensure adherence to the prescribed intensity. Additionally, each session included a 10-minute warm-up and a 5-minute cool-down. Prior to the intervention, participants also attended a single educational session on healthy diet and sleep patterns.

### 2.3 Testing Protocol

Baseline and post-intervention evaluations were conducted under standardized conditions. The assessments included body mass, body mass index (BMI), waist circumference, the Cooper 12-minute run, and the 30-second chair stand test. Prior to baseline measurements, participants were invited to the laboratory in order to familiarize them with all the tests and training protocols and provided informed consent. Baseline assessments were conducted on two separate days, ensuring a minimum interval of 24 hours between each test and completed at least 72 hours before the commencement of the training program. The testing procedures were as follows:

#### 2.3.1 Measurement of body composition

Anthropometric measurements included height, weight, BMI, waist circumference (WC), hip circumference (HC), and the waist-to-hip ratio (WHR). Participants were instructed to arrive at the laboratory in the morning on the day of the test, fast for at least 12 hours, and refrain from vigorous physical activity for 48 hours. Height and weight were measured with participants wearing light clothing and without shoes, using a standard stadiometer (accurate to 0.1 cm) and a digital scale (accurate to 0.1 kg). The BMI was calculated by dividing body weight (kg) by the square of height (m<sup>2</sup>). WC and HC were measured using a flexible tape measure, with WC taken at the level of the umbilicus and HC taken from the femur trochanter major. Both measurements were recorded in centimeters (accurate to 0.1 cm), and the WHR was calculated by dividing WC by HC. All measurements were conducted during the exhalation phase, with participants standing on both feet.

#### 2.3.2 Physical fitness test

**30-Second Chair Stand Test:** Before the pre-test, participants were provided with detailed instructions, followed by a 10-second practice session. Participants began the test sitting in a 45-cm-high armless chair positioned against a wall. The investigator instructed participants to perform sit-to-stand movements as quickly and fully as possible within 30 seconds, while keeping their feet flat on the floor and their arms crossed over their chests. To ensure chair stability, an investigator braced the front leg of the chair with a foot and provided guidance and encouragement throughout the test. Another investigator counted the number of sit-to-stand cycles and timed the test. Each participant performed two trials, with the best result recorded. A 60-second rest period was provided between trials, with an additional 30-second rest period allowed between the familiarization trial and the first trial.

**Cooper test:** The Cooper 12-minute run test took place on a standard 400-meter track. Participants were encouraged to run or jog to complete as much distance as possible within the 12 minutes. At the end of 12 minutes, the total distance was immediately recorded by the investigator (in meters), and this distance was used to evaluate the participant's aerobic capacity.

### 2.4 Statistical Analysis

Data are presented as mean  $\pm$  standard deviation and were analyzed using SPSS version 26.0 (Chicago, IL, USA). The normality of the data distribution was assessed using the Shapiro-Wilk test. Paired *t*-tests were conducted to examine the statistical significance of the outcomes for pre- and post-intervention results. A significance level of  $p < 0.05$  was set for all statistical tests.

## 3 RESULTS

### 3.1 Body Composition

As shown in Table 1, participants experienced a significant reduction in body mass following the intervention (pre: 87.3  $\pm$  13.3 kg, post: 83.6  $\pm$  13.1 kg,  $p < 0.001$ ). Similarly, BMI decreased from 28.7  $\pm$  3.3 kg/m<sup>2</sup> at baseline to 27.5  $\pm$  3.4 kg/m<sup>2</sup> post-intervention ( $p < 0.001$ ). Additionally, there was a noticeable improvement in waist circumference (WC), which dropped from 97.9  $\pm$  9.9 cm to 93.8  $\pm$  10.2 cm ( $p < 0.001$ ), suggesting a reduction in central adiposity. Hip circumference (HP) followed a similar trend, decreasing from 109.2  $\pm$  7.01 cm to 106.6  $\pm$  7.2 cm ( $p < 0.001$ ). Moreover, the waist-to-hip ratio (WHR) exhibited a significant decrease from 0.89  $\pm$  0.04 to 0.87  $\pm$  0.04 ( $p < 0.001$ ), further highlighting the reduction in central fat distribution. These results suggest that MICT is effective in promoting weight loss and reducing both overall and central adiposity, including improvements in fat distribution, as reflected by the decrease in WHR.

**Table 1** Results of Body Composition and Physical Fitness

	Pre	Post	<i>p</i>
Body mass(kg)	87.3 $\pm$ 13.3	83.6 $\pm$ 13.1	<0.001
BMI(kg/m <sup>2</sup> )	28.7 $\pm$ 3.3	27.5 $\pm$ 3.4	<0.001



WC(cm)	97.9±9.9	93.8±10.2	<0.001
HP(cm)	109.2±7.01	106.6±7.2	<0.001
WHR	0.89±0.04	0.87±0.04	<0.001

Observed values are expressed as means  $\pm$  standard deviation. BMI: body mass index, WC: Waist circumference, HP: Hip circumference, WHR: Waist Hip Ratio

### 3.2 Physical Fitness

After the eight-week MICT intervention, Significant enhancements in both aerobic capacity and LE muscle strength were observed among the participants. Firstly, the Cooper 12-minute run (12CR) distance increased (pre: 1972  $\pm$  232.6 m, post: 2204  $\pm$  257.0 m,  $p < 0.001$ ), highlighting improved cardiovascular fitness. Additionally, the number of repetitions in the 30-Second Chair Stand Test (30CST) increased from 27.2  $\pm$  4.7 to 29.9  $\pm$  5.7 ( $p = 0.002$ ), indicating a notable improvement in functional LE muscular strength (Table 2).

**Table 2** Results of the Functional Capacity

	Pre	Post	<i>p</i>
12CR (m)	1972±232.6	2204±257.0	<0.001
30CST(repetitions)	27.2±4.7	29.9±5.7	0.002

Observed values are expressed as means  $\pm$  standard deviation. 12CR: Cooper 12-minute run, 30CST: 30-Second ChairStand Test.

## 4 DISCUSSION

Significant improvements in both body composition and physical fitness were observed among overweight and obese young men following the eight-week moderate-intensity continuous training (MICT) intervention. These findings are consistent with previous studies, further supporting the efficacy of MICT in reducing body weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio (WHR), as well as enhancing cardiovascular fitness and functional LE muscular strength [3,7]. MICT has been proven to be an effective, safe, and practical exercise modality, particularly suitable for populations with a lack of physical activity experience, such as overweight and obese university students.

Waist circumference (WC) and waist-to-hip ratio (WHR), both important markers of central obesity, are closely associated with cardiovascular risk and metabolic disorders [8]. The reductions in waist circumference and WHR observed in this study suggest that MICT is effective in reducing central fat distribution. Regular moderate-intensity exercise promotes sustained fat oxidation, leading to a gradual reduction in visceral fat [9]. This is particularly important for overweight and obese individuals, as central obesity is a major predictor of cardiovascular morbidity and mortality [8].

After the intervention, the increase in Cooper 12-minute run distance demonstrated significantly enhanced aerobic capacity in participants. This is a crucial outcome, as improvements in aerobic fitness are strongly associated with better health outcomes in overweight and obese populations. Studies have shown that even moderate improvements in aerobic capacity can lower the risk of cardiovascular disease, diabetes, and overall mortality [10]. Additionally, the significant increase in the number of repetitions in the 30-Second Chair Stand Test reflects improved functional LE muscular strength, which is essential for functional mobility and daily activities. Overweight and obese individuals often experience lower LE muscular fitness due to excess body weight, making these improvements particularly valuable for enhancing quality of life [11].

## 5 LIMITATION

The 8-week moderate-intensity continuous training intervention, while demonstrating significant benefits for overweight and obese young men, has several limitations. Firstly, the study sample were young male university students, which restricts the generalizability of the findings to other populations, such as females, older adults, or individuals with more diverse health conditions. Future research should include a more diverse population in order to evaluate the impacts of MICT among various age cohorts and genders. Second, the study primarily focused on body composition and basic fitness measures, such as aerobic capacity and muscular endurance. While these are important health indicators, more comprehensive assessments, including metabolic markers (e.g., insulin sensitivity, lipid profiles), psychological outcomes (e.g., motivation, mental well-being), and long-term follow-up data, would provide a more holistic view of the benefits of MICT. By addressing these limitations, future research can further validate and expand upon the findings, providing a deeper understanding of the role of MICT in managing obesity and enhancing health outcomes in diverse populations [12].

## 6 CONCLUSION

In conclusion, the 8-week moderate-intensity continuous training (MICT) intervention demonstrated significant benefits in improving body composition, cardiorespiratory fitness, and muscular fitness, verifying its effectiveness as a weight management strategy to enhance physical fitness in overweight and obese young men.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# THE IMPLEMENTATION OF THE "DOUBLE REDUCTION" POLICY IN CHINESE PRIMARY AND SECONDARY SCHOOLS: AN ANALYSIS OF THE POLICY FRAMEWORK AND IMPLEMENTATION STRATEGY

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**Abstract:** This research revolves around China's "Double Reduction" policy in the compulsory education phase, delving into the policy framework and implementation strategies to reveal the historical context and evolving focal points of student burden alleviation. The paper initially asserts the necessity of transitioning from reinforcing to innovating in education governance and then analyzes the shifting role of co-education between home and school in reducing students' burdens. From a multidimensional perspective, the study examines the impact of complex factors such as the elitist education ideology and the exam-oriented mindset on alleviation efforts. The paper proposes that through systematic design and multi-party participation, the transformation of education governance can be propelled, empowering teachers and stimulating family education support to jointly tackle challenges in the process of student burden reduction. Ultimately, in light of current execution difficulties, the paper offers specific recommendations for improvement, hoping to provide insights for the in-depth development of China's compulsory education reform.

**Keywords:** Double reduction policy; Education governance ;Home-school co-education; Education reform

## 1 INTRODUCTION

In today's society, education is the cornerstone of national development and the guide for the future. Its importance is self-evident. With the rapid economic growth and increasingly fierce social competition, China's primary and secondary education has also experienced unprecedented development and changes. In this process, the problem of the academic burden of primary and secondary school students has gradually become prominent, attracting widespread attention from all walks of life. To this end, the Chinese government officially introduced the "double reduction" policy in 2021, that is, to reduce the homework burden and off-campus training burden of students. Its core purpose is to optimize the educational ecology and promote the all-round development of students. The appeal of the "double reduction" policy is not groundless, but is bred on the fertile soil of decades of education reform. This not only involves structural changes in regulating school operation, reorganizing the education management and evaluation system, but also requires extensive governance of the participation of the whole society in education, including individual parents. Reducing the burden is essentially a complex process of change and integration involving educational concepts, policy implementation, and the transformation of the roles of both teaching and learning. Although relevant burden reduction measures have been proposed and promoted many times before, the actual effect does not seem to have met expectations, and there is even a suspicion of "loud thunder but little rain". This can't help but trigger people's deep thinking about the difficulty of reducing the burden. In analyzing the necessity of implementing this policy, we can see that the traditional elite education concept still exists, schools tend to take exams in order to improve the admission rate, and parents blindly pursue tutoring. These factors make it difficult to reduce the burden on students and restrict the progress of reducing the burden on education. Through in-depth research, this article proposes that in order to truly promote the work of reducing the burden on students, it is necessary to start with system design and multi-party participation. The innovation of education governance should transform from single management to multi-governance, strengthen the interaction and cooperation between home and school, and stimulate the positive role of families in reducing the burden on education. This study is titled "The Implementation of the 'Double Reduction' Policy in China's Primary and Secondary Schools: Analysis of Policy Framework and Implementation Strategy", and strives to provide profound insights and constructive suggestions on the design logic, implementation difficulties and challenges of the "double reduction" policy through systematic research. In order to achieve the fundamental purpose of promoting the healthy growth of students throughout society, solve the burden reduction problem for many years, and contribute substantial intellectual support to China's deepening of compulsory education reform and promoting educational equity and high-quality balanced development.

## 2 IS IT A CHRONIC DISEASE OR A NEW DISEASE? THE HISTORICAL CONTINUATION AND FOCUS CHANGE OF REDUCING THE BURDEN ON PRIMARY AND SECONDARY SCHOOL STUDENTS

### 2.1 Standardizing School Operation: from Limited Weakening of Teaching to Consciously Strengthening Education

In the historical process of reducing the burden on students, standardizing school operation has always occupied a pivotal position. The gradual transition from the traditional teaching model oriented to scores and test scores to the current comprehensive development education that strengthens education not only reflects the change of educational concepts, but also shows the direction of China's primary and secondary education reform.

Schools are the main battlefield for imparting knowledge and cultivating talents. Under the guidance of the "double reduction" policy, the education department began to change from mandatory acceptance of knowledge to guiding students to consciously perceive and build a knowledge system. This change is not a simple change of method, but involves a deep innovation of educational concepts. Its core is to transform students' learning motivation from external promotion to internal consciousness. Traditional teaching focuses more on the inculcation of knowledge, while neglecting the cultivation of non-intellectual factors such as students' moral cultivation, creativity, and collaboration ability. This one-sided pursuit of scores has restricted students' all-round development to a certain extent. At present, the process from limited weakening of teaching to conscious strengthening of education is a direct challenge and necessary correction to this one-sided concept.

In practice, schools should weaken pure exam-oriented education and enhance students' comprehensive literacy, focusing not only on the development of students' intelligence, but also on the cultivation of their personality. This requires schools to explore diversified teaching methods and activity arrangements in the teaching process, combining traditional classroom teaching with practical activities and experiential learning, and through the reform of curriculum structure and teaching methods, allowing students to discover and solve problems in a more relaxed and free environment, thereby improving their ability to solve practical problems.

In terms of resource allocation, schools should optimize and integrate according to the requirements of the "double reduction" policy, reasonably allocate educational resources, and ensure that every student can enjoy fair and high-quality education. This requires not only that schools achieve a balance in hardware facilities, but also scientific planning and innovation in teaching staff, curriculum content, and teaching methods to ensure the continuous improvement of education quality.

In the process of educating people, the reform of evaluation methods is also imminent. The school's evaluation system should be transformed from a single test score to a comprehensive quality evaluation. Through a comprehensive evaluation system of students' quality, ability, attitude and other dimensions, it can truly reflect students' learning outcomes and development potential. Teachers need to provide personalized guidance and evaluation based on students' individual differences to promote students' personalized development.

In summary, the standardized school operation under the background of the "double reduction" policy has brought earth-shaking changes to traditional teaching. From limited weakening of teaching to conscious strengthening of education, this process requires not only systematic planning and long-term promotion by schools, but also the coordination and cooperation of society, family and school to form a win-win situation. Through conscious strengthening of education, the fundamental purpose of education can be truly realized - cultivating socialist builders and successors who are adaptable to the development of the times and develop comprehensively.

## **2.2 Education Management and Evaluation: from Strengthening the Improvement of Government Supervision to Promoting the Diversification of Enrollment Selection**

Education management and evaluation are key means to ensure the quality of education and achieve educational equity. In the field of primary and secondary education in China, with the implementation of the "double reduction" policy, the requirements for education management and evaluation are also changing significantly. Historically, education management has often focused on government supervision and administrative intervention to ensure unified management and standardized operations. However, this model has, to a certain extent, ignored the diverse educational needs and personalized educational goals.

In terms of strengthening the improvement of government supervision policies, the government has established a more stringent education quality monitoring mechanism, such as evaluating the education and teaching quality of schools through regular education and teaching supervision and evaluation, student academic level monitoring, etc. These measures ensure the uniformity of teaching standards and the basic guarantee of education quality. However, such regulatory measures also have certain drawbacks, such as the possibility of causing schools to pay too much attention to government assessment standards rather than the comprehensive development of students.

In response to this problem, under the "double reduction" policy, more emphasis is placed on the improvement of the evaluation mechanism, that is, from a single government supervision to a diversified evaluation system. This system not only includes the government's regulatory role, but also attaches more importance to the school's own internal evaluation, social forces and parental participation. Specifically, schools need to build an evaluation system covering multiple dimensions of education, teaching process and student development, and introduce the participation of third-party evaluation agencies to form a diversified and three-dimensional education evaluation system.

In terms of promoting the diversification of enrollment selection, the traditional selection method relies too much on standardized test scores, while the "double reduction" policy attempts to change the traditional selection method through various means, such as comprehensive quality evaluation, independent enrollment pilot, etc., to promote the diversification of evaluation systems and selection methods, but faces many challenges in the process of implementation, such as the need for time to change evaluation concepts and reform the selection mechanism, and the cultivation of diversified capabilities.

Overall, the reform of education management and evaluation emphasized by the "double reduction" policy aims to form a more fair, reasonable and comprehensive education system that can promote the development of students. This requires the cooperation and joint efforts of education administrators, teachers, students and parents, so as to pay attention to students' grades while paying attention to and promoting the improvement of students' comprehensive literacy, and promote the development of my country's basic education in a more inclusive and fruitful direction.

### **2.3 Governance of Social Forces in School-Running: from Passive Resistance within Schools to all-round Regulations, Restrictions and Governance**

The measures to govern social forces in school-running have gradually changed from passive response within schools to all-round regulations, restrictions and governance under the "double reduction" policy for primary and secondary schools in China. Historically, schools have often adopted a passive attitude when facing fierce competition from external tutoring institutions, and even ignored the potential impact of the growth of social school-run forces on the increased academic burden on students. Now, under the guidance of policies, strategies aimed at fundamentally solving the problem have begun to be gradually implemented.

Under the new policy environment, the government has set clear regulations for various private education institutions, including but not limited to restrictions on business hours, review of teaching content, certification of teaching staff, and assessment of the impact on students' academic performance. The strict implementation of these regulations aims to confirm the auxiliary role of private institutions and prevent them from becoming the dominant force that exacerbates students' academic pressure. Furthermore, the government's regulatory measures have gradually shifted from *ex post* punishment to *ex ante* review and continuous supervision, in order to reduce the incidence of violations at the source.

As the main body of education, schools are no longer unilaterally enduring or resisting in the process of dealing with external social school-run forces, but have become active participants in governance in accordance with the requirements of the "double reduction" policy. For example, schools need to monitor the advertising they receive to prevent commercial tutoring classes from using school platforms to mislead students and parents. And carry out internal reforms, such as optimizing curriculum settings and improving classroom efficiency, thereby reducing students' need for extracurricular help.

On this basis, the government guides social school-running forces to serve the improvement of educational equity and education quality, such as supporting students in poor areas to obtain more resources and attention. Under the new policy, private education institutions need to assume public welfare responsibilities and help narrow the gap in urban and rural educational resources.

At the same time, all-round governance also pays attention to the construction of legal and ethical frameworks. The policy requires the establishment and improvement of relevant laws and regulations, the strengthening of the construction of law enforcement and regulatory agencies, and the improvement of the sense of responsibility and law enforcement level of regulatory personnel through training and guidance. In addition, the policy encourages all parties inside and outside the school to establish good communication channels and jointly create a transparent and fair learning environment.

In addition, the standardized management of social school-running forces and the effective implementation of government supervision have laid the foundation for the comprehensive improvement of the quality of national education. The compliant operation of private education institutions not only provides students with safer and higher-quality tutoring, but also promotes the optimization and adjustment of the entire education system at a macro level.

In summary, under the guidance of the "double reduction" policy, China's management of social school-run forces in primary and secondary schools is moving in a more systematic, standardized and comprehensive direction, aiming to reduce the burden on students, increase educational equity, and ultimately promote the overall improvement of the national education level.

### **2.4 Calling on Parents to Support the Reduction of Burden: from Collaborators to Participating Subjects**

In the broad context of discussing the issue of reducing the burden of primary and secondary school students, parents, as key participants in the education process, have an increasingly stronger role and influence. The policy of reducing the burden on students places special emphasis on home-school cooperation, advocating that parents change from the traditional role of collaborators to the main body of educational participation. This change is not only a repositioning of the role of parents, but also a deep exploration of the functions and responsibilities of family education.

The traditional family education model often relies on parents to supervise and cooperate with the school's work, that is, to urge children to complete their homework and participate in various activities arranged by the school. In the context of the "double reduction" policy, the role of parents needs to undergo a fundamental change. Parents should not only assist schools in reducing students' homework and extracurricular burdens, but also become participating subjects, explore students' interests with schools, stimulate their innovative potential, cultivate appropriate learning methods, and create conditions conducive to the all-round development of their children in the family environment.

First, effective home-school communication is the basis for parents to support the work of reducing the burden. Parents need to establish a regular communication mechanism with teachers to understand their children's learning status, mental health, and social skills development at school. Through effective communication, parents can provide more

personalized family support, help children develop reasonable study plans, balance study and rest time, and thus reduce unnecessary burdens.

Second, parents should become participants and partners in education. In daily life, parents should communicate knowledge and interact emotionally with their children through various forms such as reading, discussion, and games, which not only promotes the harmony of family relationships, but also helps children form a positive attitude towards life.

Third, parents should attach importance to their own exemplary role in education. Parents' words and deeds have an important impact on their children. Parents should establish correct educational concepts and values, avoid excessive attention to scores and rankings, and focus on improving their children's comprehensive abilities. Parents' ideas and behaviors set an example for their children invisibly and have a profound impact on their children's growth.

Fourth, the renewal of parents' ideas is the key to supporting the policy of reducing the burden. Parents must realize that the pursuit of enrollment rate and scores is not the only goal of education, but should pay attention to the health and happy growth of their children. Parents are encouraged to relax their minds, set reasonable expectations, and encourage their children to try in many aspects, rather than just investing energy in exam-oriented education.

In summary, parental support is crucial to reducing the burden on students and optimizing the educational environment. Only when parents are willing to take on the role of participating subjects can they form a joint force of education with the school and truly achieve the goal of reducing the burden on students. To this end, it is necessary to guide and train parents, enhance their awareness and ability to participate in education, and jointly build an efficient and harmonious educational ecosystem.

### **3 WHY IS THERE SO MUCH NOISE BUT LITTLE RAIN? THE COMPLEX CAUSES OF THE DIFFICULTY IN REDUCING THE BURDEN ON STUDENTS FROM A MULTI-DIMENSIONAL PERSPECTIVE**

#### **3.1 Social Level: the Concept of Elitist Talent Training is Still Prevalent**

When deeply understanding the complex background and challenges of China's "double reduction" policy for primary and secondary schools, we cannot ignore the deep-rooted elitist talent training concept at the social level. Although the introduction of the "double reduction" policy is aimed at alleviating the heavy academic burden on students, the widespread pursuit of elite education in society has caused considerable resistance in the implementation of the policy.

The core of the elitist education concept is that selective education can cultivate a small number of outstanding talents, thereby promoting the development of social elites. This concept has, to some extent, strengthened the test-oriented education and score-oriented teaching model. In order to pursue high scores and enter prestigious schools, parents and students are willing to invest huge time and money resources in tutoring and training. With the intensification of market competition and the development of international education trends, this elite training model seems to have become the only way to success.

By analyzing the current situation of the education market, we can find that even after the implementation of the "double reduction" policy, the competition for high-quality educational resources in society has not decreased. The particularity of China's education structure is that elite schools often have scarce resources and can provide better education channels, which makes parents and students more desperate to pursue opportunities for further study in order to stand out. At the same time, the college admission system emphasizes standardized test scores, which invisibly increases the importance of students and parents on academic performance.

In this context, individual educational achievements are regarded as an important way for social mobility, so families and society tend to invest more in early education so that students can occupy a favorable position in future competition. Due to the lack of understanding and confidence in the long-term positive impact of the "double reduction", many parents choose to bypass regulations and continue to look for off-campus training institutions or private teachers to ensure that their children do not fall behind in the competition for further study.

Educational equity is another problem that the "double reduction" policy attempts to solve, but in a social environment where elitism prevails, the inequality that should have been improved by policy tendencies is at risk of being further strengthened.

Macroeconomic growth and technological progress require highly skilled and innovative talents, but ignore the all-round development of the majority of students, which has led to the influence of elitist education concepts. To change this phenomenon, it is necessary to improve the quality of education for all students, re-evaluate the admission selection system, and strengthen the publicity and investment in vocational education. Policymakers, education managers and the whole society should participate together to form a concerted effort to promote the reshaping of education concepts and improve the overall effectiveness of the education system.

#### **3.2 School Level: The "Admission Only" Education Performance View Remains Popular**

Although my country continues to implement the "double reduction" policy aimed at relieving students' pressure, schools still use academic performance as a criterion. The so-called "admission only" reveals the current popular concept of education performance, that is, the main evaluation criterion of schools is whether students can successfully advance to higher education. Although policy adjustments have attempted to shift the focus to a comprehensive education approach, this tendency to regard academic advancement as the core indicator of school performance has not

significantly weakened.

For a long time, the evaluation system constructed by schools has focused on high scores and admission rates, which has exacerbated the "academic achievement as the core" mindset. School administrations and teachers are often caught in a dilemma, as their professional achievements and school reputations depend heavily on students' performance in highly competitive entrance exams. As a result, schools tend to focus more resources and time on improving students' performance in these exams, sometimes at the expense of students' non-academic development and overall well-being. This common view is closely linked to the complex relationship between socio-cultural expectations and the local educational ecosystem. In areas where academic success is highly competitive, parents and policymakers attach great importance to schools. These schools are under constant pressure to maintain or improve their rankings and status through student performance indicators. As a result, an environment has been formed that favors an academic-focused approach rather than a holistic educational experience.

In addition, the lack of an appropriate evaluation system to fully recognize and reward schools' contributions to student development in areas other than academics has led to a long-term ingrained concept of "admission-only". Schools are therefore driven to focus on quantifiable achievements, which are often seen as the most intuitive and significant basis for parents, the public, and education authorities to evaluate school effectiveness. This institutional bias has limited the core goals of education to a limited scope, thereby offsetting the widespread implementation of the concept of holistic education advocated by policies such as "double reduction".

Although the "double reduction" policy aims to solve a series of problems by reducing homework and extracurricular tutoring, its actual effect is still weakened by the traditional concept of educational success.

To achieve a more comprehensive education model, we need to redefine school performance indicators, widely recognize student achievements, promote educational practices that value personal development and academic strength, and create an environment that truly embodies the spirit of the "double reduction" policy. Educators, parents, and policymakers need to work together to redefine the meaning of excellent education and value the comprehensive development of each student, not just their test scores.

In summary, the "double reduction" policy highlights the need for education reform and student burden reduction, but the entrenched "admission-only" view requires concerted efforts to shift the school-level view of educational performance to a more balanced and comprehensive view that values school education performance. All aspects of student development. This paradigm shift is not only crucial to the success of the "double reduction" policy, but also to the long-term health of China's education system and the well-being of students.

### **3.3 Family Level: Parents Still Have Misunderstandings about Reducing the Burden of Education**

When discussing the background and challenges of China's "double reduction" policy for primary and secondary schools, it is important to not underestimate the misunderstandings of parents about reducing the burden of education at the family level. According to the latest research, although the country has vigorously promoted the reduction of students' academic burden, there is still a general misunderstanding among parents about effective ways to reduce the burden. Some parents showed obvious hesitation and conservative attitudes when accepting the concept of education reform. The contradictory psychology appeared between balancing traditional values and modern education requirements, which brought obstacles to the implementation of the policy of reducing the burden.

First, some parents mistakenly equate reducing the burden of education with reducing the quality of education and academic requirements. This misunderstanding stems from a misunderstanding of the nature of education. They believe that a tense learning atmosphere and heavy schoolwork are the guarantee of academic success. For example, some parents worry that the "double reduction" will affect their children's advantage in the fiercely competitive entrance examination, believing that it will weaken their children's competitiveness in knowledge acquisition and skill mastery.

Second, parents tend to rely too much on training institutions and regard additional educational services as a necessary condition for their children's success. They worry that the "deficiencies" of school education need to be compensated by extracurricular tutoring. This misunderstanding has led parents to send their children to various tutoring institutions even though the government has explicitly banned training institutions from teaching beyond the syllabus and operating without a license, further exacerbating the children's academic pressure and running counter to the original intention of the "double reduction" policy.

Third, some parents believe that the real burden reduction should be to completely eliminate homework. This perception ignores the important role of homework in consolidating learning outcomes and cultivating students' self-learning ability. Instead of absolutely denying homework, a more rational approach is to adjust the form and content of homework to make it an auxiliary tool in the learning process rather than an incremental burden.

Therefore, we can see that parents' misunderstanding of burden reduction is one of the important challenges facing the "double reduction" policy. In order to effectively promote the reduction of education burden at the family level, it is necessary to provide parents with comprehensive and in-depth education to help them understand the correct meaning of burden reduction and adjust their expectations and attitudes towards their children's education, so as to fundamentally support and promote the implementation of the policy. This is not only related to the success or failure of a policy, but also directly related to the happy growth of the next generation and the long-term development of society.

### **3.4 Fundamental Problem: Test-oriented Thinking Still Dominates Education Practice**

Test-oriented thinking is deeply rooted in the field of education and can be regarded as the "fundamental problem" in current education practice. This mode of thinking emphasizes the evaluation of students' learning effects and abilities through test scores, which leads educators, students and parents to pay too much attention to scores and test results, while neglecting the cultivation of students' personality development, innovation ability and comprehensive quality. Even in the context of the introduction of the "double reduction" policy, test-oriented thinking is still difficult to fundamentally weaken, and there are many reasons for this.

First, the traditional functions of examinations and selection are still deeply rooted in people's hearts. In today's education system, especially in the process of admission, test scores are still an important selection tool. Whether entering a better junior high school, high school or university, students need to pass a series of exams and assessments. This model of selection based on grades continues to strengthen the foundation of exam-oriented education.

Second, when faced with the two key indicators of education evaluation system and admission rate, schools often adopt an education model that conforms to the test-oriented approach. These external pressures force schools to focus on improving students' scores and pass rates, rather than the comprehensive development of students' abilities. This score-oriented teaching model not only affects teachers' teaching methods, but also limits the comprehensive development of students' cognition and skills.

At the family level, parents usually hope that their children can achieve excellent academic results, because in the general cognition, good grades are equivalent to having more future choices and better social status. This concept has encouraged parents to give their children excessive educational guidance and tutoring, making exam-oriented education dominant in family education practice.

On the other hand, market demand has also contributed to the prevalence of exam-oriented education to a certain extent. Training institutions have flourished by highlighting the effect of improving scores and satisfying parents and students' desire for high scores. Even the strict restrictions on off-campus training under the "double reduction" policy still cannot completely change the needs of parents and students for this.

In the face of this crux, in order to completely change the test-oriented thinking, it is necessary to start from multiple angles, such as the transformation of educational concepts, the reform of the education evaluation system, the comprehensive evaluation of student development, and the improvement of social tolerance, so as to achieve deep-level changes in educational practice. The government, schools and families should also work together to jointly cope with the challenges brought by exam-oriented education.

Therefore, changing the dominance of test-oriented thinking is not a one-off process, but a long-term task that requires the coordinated promotion of various forces inside and outside the education system. Only by reforming educational concepts, evaluation systems, improving social tolerance, and refining policy implementation can we hope to solve the "fundamental crux" in this educational practice at the root.

#### **4 How to Break the Deadlock in Reducing the Burden: Moving Towards System Design and In-Depth Participation of Multiple Parties**

##### **4.1 Improve Education Governance: Transform Education "Bad Governance" to "Good Governance" and "Co-Governance"**

In the process of deepening the "double reduction" policy for primary and secondary schools, the problem of "bad governance of education" has become a difficult problem that cannot be ignored. The so-called "bad governance of education" mainly refers to the governance model centered on exam-oriented education, which ignores the comprehensive development needs of students, resulting in unfair distribution of educational resources, uneven teaching quality of schools, increased pressure on family education, and excessive physical and mental burden on students. To change this situation, it is necessary to fundamentally change the governance thinking and move towards a new education governance model of "good governance" and "co-governance".

First, "good governance" requires policy makers and implementers to optimize students' learning experience and living conditions as the core, and constantly search and practice more scientific and fair education management methods. This includes promoting student-centered education concepts and learning methods, and paying attention to cultivating students' diverse abilities rather than just subject scores. Taking the "double reduction" policy as an example, by reasonably setting teaching content, adjusting homework burden, and controlling off-campus training institutions, the policy aims to build a more relaxed and diverse education ecology to stimulate students' learning interest and innovation ability.

Secondly, "co-governance" means that through the joint participation and efforts of the government, schools, families and all sectors of society, the democratization and socialization of education governance will be achieved, and the equity and quality of education will be jointly promoted. The government plays the role of policy guidance, supervision and service provider, focusing on building platforms, improving mechanisms, and promoting coordination and cooperation among multiple subjects. As the direct supplier of education, schools need to optimize internal management, give full play to their professional advantages, and focus on educational research and innovation. As partners, families should not only actively participate in their children's education process, but also look at education and further education issues rationally, and provide children with a good family learning environment and psychological support. In addition, social organizations and the media should also join in education governance to provide more abundant educational resources and supervision support.

Specifically at the policy implementation level, it is necessary to promote the transformation of education governance



from the following aspects. First, the government should increase its financial investment in schools, especially support for schools in rural and urban marginal areas, improve educational infrastructure, and narrow the urban-rural and regional education gaps. Second, the government should regulate off-campus training institutions through legal channels, control their number and business scope, as well as course content and time arrangements, and prevent excessive commercialization and test-oriented tendencies. Third, the education department needs to comprehensively reform the education evaluation system, establish an evaluation mechanism oriented towards promoting the all-round development of students, reduce and standardize the number of examinations, and reduce the pressure of taking examinations.

In terms of promoting home-school co-education, schools should improve teachers' parent work skills, actively convey correct educational concepts and methods to parents, organize parent schools and family education consulting services, and guide parents to improve the quality of family education. At the same time, the establishment and operation of parent organizations such as parent meetings should be encouraged and supported, so that parents can more effectively participate in and supervise school teaching management and services.

Finally, to achieve "good governance" and "co-governance", we must also emphasize cross-border cooperation and innovation. Education governance is no longer a matter of a single department or a single level, but requires cross-disciplinary, cross-departmental and social cooperation to jointly explore and practice the best way of education governance.

Therefore, the improvement of education governance lies in the transformation from "bad governance" to "good governance" and "co-governance". This requires us not only to think about and improve the current situation of education from the policy and system level, but also to mobilize the power of all education participants from the practical level, in order to build a balanced, fair and high-quality education environment, so that students can thrive in a relaxed and pleasant atmosphere.

#### **4.2 Consolidate the Position of Educating People: Respect and Affirm Teachers' Work, Strengthen Home-School Co-Education, and form a Mutual Assistance Mechanism**

In the process of exploring the implementation of the "double reduction" policy in China's primary and secondary schools, an important part that cannot be ignored is to consolidate the position of educating people. The position of educating people is not only in the classroom of the school, but also extends to the comprehensive cooperation network of teachers, parents and the community. The core of this section includes respecting and affirming teachers' work, strengthening home-school co-education, and forming a mutual assistance mechanism between teachers and parents. The three complement each other and jointly promote the improvement of students' comprehensive quality.

1. Respecting and affirming teachers' work is the basis for consolidating the position of educating people. As the implementer and disseminator of education, the degree of recognition of the professional value of teachers directly affects the quality of education and the stability of the teaching staff. Under the "double reduction" policy, the workload of teachers has changed greatly, and the nature of their work has also changed, but their work in leading students to explore true knowledge, cultivate quality, and stimulate interest is indispensable. Therefore, education administrators should give full respect and affirmation to teachers' work, improve teachers' labor remuneration and career promotion system, and protect teachers' professional growth space and social status, so that they can devote themselves to education and teaching activities.

2. Strengthening home-school co-education is the key to creating a positive education environment. The essence of home-school co-education is the interaction and cooperation between family education and school education. The benign interaction between the two can significantly improve the effectiveness of education. Under the "double reduction" policy, the collaboration between home and school is more important. Parents should understand and support the school's educational philosophy, participate in every bit of their children's learning process, and create a good family learning atmosphere for their children. Schools should regularly organize parent meetings, educational lectures and home visits to understand parents' demands and confusions and provide professional educational guidance and support.

3. Forming a mutual assistance mechanism is an effective way to consolidate the education front. The relationship between teachers and parents should not be a simple information transmission relationship, but a more in-depth partnership. For example, a normalized communication platform can be established to allow parents to participate in the design and evaluation of teaching activities and enhance the consensus of both parties on educational goals. Similarly, teachers can learn about students' family background and learning situation from parents, adjust education strategies, and meet the personalized needs of different students.

4. To achieve the consolidation of the education front, it is also necessary to strengthen teacher training, strengthen teaching resource construction, and improve education evaluation mechanisms. Only through such systematic reforms can we truly build an educational ecosystem based on student development and promote students' comprehensive and balanced growth.

#### **4.3 Focus on Teacher Empowerment: Guarantee Their Teaching Research and Professional Improvement Opportunities, and Improve Teacher Quality**

In the context of China's "double reduction" policy for primary and secondary schools, teachers are key factors in education quality and student development, and it is particularly important to strengthen support for their abilities and

career development. Teacher empowerment largely determines the implementation effect of the education burden reduction policy and the improvement of education quality.

1. The primary focus of teacher empowerment is to improve the professional level of teachers. According to the latest statistics from the education department, the overall education level of China's primary and secondary school teachers is improving with the times, but in the process of pursuing the improvement of education quality, there are still many bottlenecks in the professional development of teachers. For example, there is a lack of sufficient personalized and innovative teaching methods in educational practice, there are not enough examples of combining academic research with teaching practice, and opportunities for continuing education and professional development are relatively limited.
2. Effectively improve the quality of teachers and enrich teaching research opportunities. This means not only providing sufficient time and resources to support teachers in conducting research projects, but also ensuring that teachers have the opportunity to participate in a wider range of academic exchanges. Many studies have pointed out that teachers' participation in research activities can significantly improve their teaching methods and improve the quality of education for students.
3. The key to improving teachers' quality also lies in improving their working environment and incentive mechanism. Relevant studies have shown that teachers' job satisfaction and professional happiness have a direct impact on improving teaching effectiveness. Therefore, shaping a positive and supportive educational working environment and formulating reasonable incentives are crucial to attracting and retaining excellent teachers and thus improving the quality of education.
4. The dual challenge of changing traditional teaching concepts and methods. Schools and educational management agencies need to hold professional training, workshops and academic seminars. These activities should focus on the core issues of the current educational revolution, such as students' independent learning, the cultivation of critical thinking and the educational application of information technology.
5. Construct a reward system to stimulate teachers' motivation for continuous learning and improvement. An effective career development path can clarify teachers' growth direction and goals, and encourage them to explore and learn continuously in their careers. The reward system can improve teachers' professional vitality and innovation ability by affirming the results of their teaching and research.

#### **4.4 Arouse Family Support: Enhance Parents' Sense of Responsibility and Guide Them to Take Substantive Actions**

In the process of in-depth analysis of the "double reduction" policy framework and implementation strategy, we cannot ignore the importance of the family. Especially in terms of enhancing parents' sense of responsibility and guiding them to take specific actions.

1. The family is the primary environment for children to grow up. In traditional concepts, many parents may prefer to hand over the responsibility of education entirely to the school, thus ignoring their own role in education. However, one of the core of the implementation of the "double reduction" policy is to advocate home-school co-education, strengthen the status of the family as the main body of education, and let parents realize that in addition to school, family education is equally important.
2. Improve parents' sense of responsibility. Organize parent education activities through various channels such as education departments and communities, popularize scientific parenting knowledge and methods, and let parents understand that reducing academic burdens does not mean letting children go, but guiding their children to grow in a more reasonable way. For example, educate parents on how to communicate effectively with their children, how to set appropriate learning goals, and how to create an atmosphere conducive to learning in the family environment.
3. Concrete parental responsibilities through institutional design. For example, through regular parent meetings, homework tutoring, and parent-child activities, parents can play a more active role in the learning process of students. In addition, parents' participation in school management and decision-making processes can greatly improve their sense of responsibility and participation, and at the same time strengthen the school's self-management and reflection on the quality of education.
4. Guide parents to take substantive actions. Specifically, we can start from the following aspects: First, establish a home-school contact system, such as the parent volunteer program, to encourage parents to participate in the daily operation of the school. Secondly, use modern information technology means, such as campus networks and home-school interactive platforms, to facilitate parents to understand their children's learning situation and school dynamics in a timely manner, and to facilitate parents to provide feedback and suggestions. Through such channels, parents can participate more directly in their children's education process, and form good interactions with teachers to jointly promote the all-round development of their children.

In short, to realize the positive role of the family in the "double reduction" policy, it is necessary to start from two aspects: enhancing parents' sense of responsibility and guiding practical actions. Through multi-level and multi-means cooperation and interaction, we will eventually encourage families and schools to work together to form a strong synergy to support the healthy growth of children.

## **5 WHERE IS THE WAY FORWARD: DEEPLY PONDER THE KEY PRINCIPLES OF REDUCING THE BURDEN ON PRIMARY AND SECONDARY SCHOOL STUDENTS**

With the deepening of the "double reduction" policy, how to establish the guiding principles for reducing the burden on primary and secondary school students has become an unavoidable issue. The quality and efficiency of education depend on the correctness of the concept, and the implementation of the policy cannot be separated from sufficient theoretical support and operational guidance. Therefore, on the basis of reflecting on the problems and limitations in the previous burden reduction work, it is particularly important to propose a burden reduction principle that conforms to the laws of education and fits the needs of students' growth.

1. The principle of the integrity of education cannot be ignored. Education is not only the responsibility of the school, but also a process of joint participation of the family, school and society. The healthy growth of primary and secondary school students requires the creation of a harmonious family atmosphere, scientific school education and a positive social environment, all of which are indispensable. The implementation of the "double reduction" policy should focus on building an educational synergy of home-school-community cooperation, co-education and co-governance, strengthen communication and cooperation between home and school, actively guide and utilize community resources, form an educational synergy, and break the narrow pattern of relying solely on schools to reduce the burden.

2. It is crucial to adhere to the individualized principle of teaching students in accordance with their aptitude. Primary and secondary school students are the main body of education, and each student has his or her own characteristics and interests. The "double reduction" policy should encourage schools to reform the traditional test-oriented education model, promote a diversified evaluation system, start from individual differences, pay attention to students' strengths, interests and needs, provide them with appropriate learning paths through personalized education methods, and fundamentally change the "one-size-fits-all" teaching method.

3. The principle of autonomy with the cultivation of students' autonomous learning ability as the core needs to be carried out throughout. Improving students' autonomous learning ability is one of the important goals of the "double reduction" policy. Students should become the masters of learning, and schools should cultivate students' inquiry spirit and self-management ability by designing appropriate educational activities and teaching strategies. Pay attention to the guidance of students' learning methods, so that they can cultivate interest and enthusiasm in the learning process, rather than simply pursuing scores and results.

4. The principle of universal benefit to enhance educational equity is also indispensable. The balanced distribution of educational resources is crucial to reducing the burden of family education and ensuring the quality of education. The "double reduction" policy needs to focus on the reasonable distribution of educational resources between different regions and schools, narrow the urban-rural and regional educational differences, and provide equal educational opportunities for all students, including high-quality public education resources and structural reforms to promote the sharing of high-quality education resources.

5. The principle of humanistic care to maintain the dignity of teachers' profession is the spiritual cornerstone of the implementation of the "double reduction" policy. Teachers are the leaders of educational activities and play a vital role in reducing students' burden. Support for teachers' professional growth, including providing continuous professional training and development opportunities, guaranteeing their teaching freedom and professional autonomy, and respecting and rewarding teachers' innovation and efforts, will help stimulate teachers' teaching enthusiasm and improve the quality of education and teaching.

## CONCLUSION

After an in-depth analysis of the policy framework and implementation strategies of my country's primary and secondary school "double reduction" policy, this article has reached an important reflection node. This study not only details the historical background and necessity of the policy, emphasizes the role change of home-school co-education in the process of reducing burden, but also carefully explores the impact and challenges of multi-dimensional factors on students' burden reduction, especially focusing on the profound impact of elite education concepts and test-oriented mentality on educational practice. In order to achieve the successful implementation of the "double reduction" policy, we need to broaden our horizons to a more macro social and cultural background, deepen the transformation of educational concepts and social values, and encourage the cultivation of innovation and comprehensive abilities. This requires the joint efforts of policymakers, educators, parents and the whole society. At the same time, to achieve the goal of reducing the burden, it is necessary to give teachers autonomy, stimulate their inherent potential, provide continuous professional development support, formulate a reasonable evaluation system, clarify teachers' responsibilities and rights, and build a collaborative education ecology to ensure the quality of teaching and reduce students' excessive academic pressure.

For families, the "double reduction" policy is also an educational opportunity, prompting parents to re-examine their expectations and practices for their children's education. Get rid of the score orientation and pay attention to the comprehensive growth of children. Parents need to become a solid backing to support their children's personalized development. In addition, it must be recognized that the implementation of the "double reduction" policy is not achieved overnight, but a long-term process, which requires policies and practices to go hand in hand and be continuously adjusted and optimized. Government departments and educational institutions at all levels should establish and improve supervision mechanisms to ensure that the burden reduction measures are implemented in place and not deformed, so as to provide theoretical support and practical guidance for the continuous advancement of China's education reform and create a more relaxed, healthy and happy growth environment for children and young people in my country.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# ENHANCING PROFESSIONAL ENGLISH SKILLS IN SPORTS PROGRAMS: APPLICATION AND CHALLENGES OF INTERACTIVE TEACHING METHODS

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**Abstract:** This study explores the potential of interactive teaching methods in the English teaching of sports-related programs, aiming to enhance students' professional English skills. Based on Vygotsky's sociocultural theory (SCT) and English for Specific Purposes (ESP) pedagogy, interactive teaching methods employ real-life vocational scenarios, cooperative learning, and role-playing to help students master professional terminology and communication skills in international sports events, cross-cultural exchanges, and sports management. The paper reviews existing literature, analyzes the advantages and challenges of interactive teaching, and, through the lens of constructivist theory, proposes suggestions for improving instructional practices. The study finds that interactive teaching significantly increases student engagement and language application skills, with the use of modern technologies, such as augmented reality (AR) tools, further enhancing educational outcomes. However, current sports English teaching faces challenges such as resource limitations, large class sizes, and low student engagement. This study recommends that teachers tailor curriculum design to students' needs and proposes future research directions to further verify the effectiveness of interactive teaching methods in improving professional English skills.

**Keywords:** Interactive teaching methods; Sociocultural theory; English for specific purposes; Sports english; Professional skills; Constructivism

## 1 INTRODUCTION

In the context of globalization, English has become a key tool for international communication and professional interaction, particularly in the field of sports, where English proficiency is critical for organizing international events, cross-cultural communication, and sports management [1]. Upon graduation, sports students are expected to participate in various international sports events and cross-cultural exchanges, and mastering professional English language skills is essential for their success in these activities. However, current English teaching methods struggle to meet this demand, as there is a significant disconnect between traditional teaching approaches and the requirements of sports-related professional contexts [2]. To address this issue, interactive teaching methods have been increasingly introduced into sports-related English teaching in recent years.

Although interactive teaching methods have proven effective in many language learning fields, their application in sports English education remains limited, with most existing studies focusing on theoretical discussions rather than in-depth empirical research. Thus, a key issue in this field is how to apply interactive teaching methods in sports English education to enhance students' professional skills. Interactive teaching methods are grounded in Vygotsky's sociocultural theory (SCT), which emphasizes the internalization of language through interaction and collaboration, especially within the Zone of Proximal Development (ZPD), where students can complete tasks beyond their abilities with the guidance of a teacher [3].

The primary motivation for this study is to fill the gaps in current research by exploring the potential of interactive teaching methods in sports English education. By integrating interactive teaching methods with English for Specific Purposes (ESP) pedagogy, this paper aims to analyze how these methods can improve students' language application skills in real-life professional settings. Sports students not only need to master general English language skills but also professional terminology and communication strategies required for international sports events and cross-cultural exchanges [4]. However, current teaching resources and methods are limited, and many courses lack realistic simulations of future professional scenarios, resulting in low student motivation for learning English.

The purpose of this study is to explore the advantages and challenges of interactive teaching methods in sports English education through a review of the literature and to provide specific recommendations for improvement, helping teachers better implement these methods. The paper first reviews the theoretical foundations of interactive teaching methods, then discusses their current application in sports English education, and finally offers directions for future research and instructional improvements.

In the following sections, the paper first discusses the theoretical background of interactive teaching methods, linking them to constructivism and sociocultural theory to highlight their role in language instruction. The article then explores ESP theory and its application in sports English education. Finally, the paper conducts a literature review to analyze the current shortcomings of sports English teaching and the practical application of interactive teaching methods.

## 2 LITERATURE REVIEW

### 2.1 Theoretical Background of Interactive Teaching Methods

SCT serves as one of the main theoretical foundations for interactive teaching methods. According to Vygotsky, learning is a process of social interaction, particularly in language learning, where students develop their cognitive and language skills through interaction with others. SCT emphasizes that individuals internalize external knowledge through interaction with others (teachers or peers) within the Zone of Proximal Development (ZPD) [3]. The core of this theory is to help learners complete tasks they cannot accomplish independently through interaction, thereby promoting language and cognitive development.

Interactive teaching methods, through teacher-student and peer interaction, engage students in language learning and help them internalize new language knowledge through practice. Research shows that interactive teaching effectively improves language proficiency, particularly in second language acquisition, where interaction fosters cooperation and communication within a sociocultural context, helping students understand the practical application of language [5]. Vygotsky's ZPD concept is especially important, highlighting how students, with proper guidance and support from teachers, can achieve higher levels of language proficiency through interaction [6].

In second language acquisition, SCT provides a framework where students can gradually internalize and master language through collaborative learning and interactive activities. This teaching method promotes students' understanding and application of language skills and provides opportunities for practicing in real-life contexts.

### 2.2 English for Specific Purposes (ESP) Theory

English for Specific Purposes (ESP) is a teaching theory focused on addressing students' future professional language needs. ESP emphasizes not just basic language functions but also the actual application of language in specific professional fields. In sports-related programs, for example, students need to master specialized terminology, communication skills, and industry-specific language to effectively communicate in their future careers.

According to ESP theory, vocational English teaching must be tailored to the specific needs of a profession, emphasizing practical application rather than merely learning language rules. For sports students, ESP course design should integrate sports-related professional vocabulary, oral expression, and report writing, among other practical skills [1]. However, current studies show that the application of ESP in sports programs has not been fully explored, particularly in integrating language teaching with the actual needs of sports careers.

Currently, sports English education faces several issues, including a lack of specialized teaching materials tailored to sports career scenarios, limited teaching resources, and insufficient empirical research on how to effectively improve students' professional English communication skills. These issues highlight the need for further exploration of how ESP teaching can better meet the needs of sports students [2].

### 2.3 Current Status of Sports English Education

In sports programs, the goal of English teaching is not only to improve students' language proficiency but, more importantly, to enhance their ability to apply language in international sports settings. Sports students must develop certain communication skills to succeed in areas such as international sports events, cross-cultural exchanges, and sports management. However, existing English teaching methods are often traditional and lack close integration with professional demands in the sports industry.

Research shows that sports students face several challenges in learning English, including low motivation, insufficient teaching resources, and curriculum designs that do not effectively meet career demands [2]. Moreover, students often show little interest in learning English, especially in large class settings or environments lacking interaction, which limits their improvement in English proficiency and hinders their ability to meet language requirements for future careers.

To enhance sports students' professional English skills, teaching must be closely linked to real-life vocational scenarios. Research demonstrates that interactive teaching methods significantly improve student engagement and practical application skills through simulations of real scenarios, role-playing, and cooperative learning [7]. Additionally, the use of modern technologies, such as digital tools and mobile applications, can provide new teaching models and innovative practices in sports English education [8].

## 3 THEORETICAL FRAMEWORK

### 3.1 Constructivism and Interactive Teaching Methods

Constructivist learning theory posits that knowledge is not directly transmitted from teachers to students but is actively constructed by students through interaction and practice. Based on this theory, interactive teaching methods emphasize that students construct knowledge through collaboration and interaction with teachers and peers rather than passively receiving information. Piaget, a leading figure in constructivism, argued that learning results from the cognitive development of individuals, which occurs through interactions with their environment. Vygotsky further developed

constructivism by proposing SCT, which stresses that knowledge is constructed through social interaction, especially in language learning, where interaction plays a critical role [9].

In the application of interactive teaching, the teacher's role shifts from a knowledge transmitter to a facilitator and guide. Students, through problem-solving and group discussions, actively participate in knowledge construction. In sports education, for example, interactive teaching can use teamwork and role-playing in real-life scenarios to facilitate students' understanding and application of professional English skills [10]. Studies show that such interactive methods not only increase student participation but also effectively promote deep understanding and transfer of knowledge [11].

### **3.2 SCT and Sports English Teaching**

SCT emphasizes that learning is a social process, and students develop cognitively through interaction with others. A core concept of SCT is the Zone of Proximal Development (ZPD), where students can complete tasks beyond their current ability with the support of a teacher or experienced peer. In sports English teaching, Vygotsky's theory has special significance. Sports students need to master professional language skills through practice and interaction, and teacher guidance and peer interaction play critical roles in this process [12].

In sports English education, SCT provides theoretical support for the vocational application of language. For instance, in the context of sports events or international sports management, students need to effectively communicate in English. These professional language skills can be practiced and improved through interactive teaching methods that simulate real scenarios, enhancing students' language practice abilities. Research shows that interactive teaching provides a collaborative and practical learning environment for students, helping them better master sports-related English skills [13].

### **3.3 Application of ESP**

English for Specific Purposes (ESP) focuses on providing students with specialized English training related to their future professions. For sports students, ESP course design needs to cater to the specific demands of their careers, particularly in international sports management, event communication, and sports education. Research shows that ESP can significantly improve students' professional English proficiency and help them better apply English in their future careers [14].

ESP courses emphasize not only basic language functions but also the professional context of students' backgrounds, providing highly targeted language training. Current research highlights that sports students often lack motivation, and course content does not align well with career demands. The application of ESP can use real-life scenarios, such as sports event organization and international sports communication, to help students better master language skills and enhance their professional competitiveness [15]. However, empirical research on ESP teaching in sports programs remains limited, and more studies are needed to explore its effectiveness across different cultural backgrounds and teaching environments [16].

## **4 CONCEPTUAL ANALYSIS**

### **4.1 Effectiveness of Interactive Teaching Methods in English Instruction**

Interactive teaching methods have been proven to be effective in English instruction, particularly in cultivating vocational skills. Research shows that interactive methods significantly improve students' communication and language application abilities through group discussions, role-playing, and scenario simulations. For example, Chang et al. [17] found that combining augmented reality (AR) technology with interactive teaching not only increased students' motivation but also significantly improved their performance in learning complex motor skills.

In English language instruction, interactive methods help students effectively apply English in real-world professional environments by simulating vocational scenarios such as job interviews and meeting discussions. Zhang & Zhang [18] compared traditional and interactive teaching modes, finding that interactive teaching fosters effective communication between students and teachers and enhances student autonomy and creativity. The greatest advantage of interactive teaching methods is that they provide students with real-life language application scenarios, helping them bridge the gap between language skills and vocational skills.

### **4.2 Specific Applications in Sports Programs**

In sports programs, interactive teaching methods effectively enhance students' communication skills in sports events and their use of professional terminology. Sports students need to acquire specific English skills, especially for communication in cross-cultural sports events. Research shows that interactive teaching methods, through simulations of real scenarios (e.g., press conferences or dialogues between coaches and athletes), help students apply English effectively in vocational contexts. Knijnik et al. [19] point out that dialogue-based teaching methods help students develop their creativity and enhance their understanding of sports terminology and rules.

Additionally, interactive teaching in sports education fosters teamwork and simulates sports-related scenarios to help students master complex sports terminology. For example, Malenko [2] found that using interactive techniques and

digital tools improves sports students' English proficiency and enhances their ability to apply professional terminology in sports management and event organization.

### 4.3 Challenges

Despite the significant effectiveness of interactive teaching methods in improving students' English skills, several challenges remain in their application. First, large class sizes often make it difficult for students to effectively participate in interactive activities, reducing the effectiveness of teaching. Malenko [2] noted that sports programs often have large class sizes, making it difficult for teachers to provide personalized guidance, leading to passive participation for some students during interactions.

Second, low student participation is another major issue for interactive teaching. Cao [20] found that although interactive teaching provides more opportunities for participation, some students, due to limited language skills or lack of confidence, may avoid participating in interactive activities, limiting the effectiveness of the teaching method.

Additionally, resource limitations are a significant challenge. Zhang & Zhang [21] highlighted that many schools lack adequate digital teaching resources or professional materials, significantly diminishing the effectiveness of interactive teaching. To ensure the success of interactive teaching methods, schools must provide more teaching resources and technical support to help teachers effectively implement these methods.

## 5 THEORETICAL DISCUSSION

### 5.1 Advantages and Disadvantages of Interactive Teaching Methods

**Advantages:** Interactive teaching methods offer numerous advantages in sports English education. First, they enhance student engagement and initiative. Through group discussions, role-playing, and other interactive activities, students can actively participate in the learning process and improve their mastery of both language and professional skills. Research shows that interactive teaching methods help students develop communication skills, particularly in sports-related scenarios such as event commentary and athlete communication. Knijnik et al. [22] highlighted that dialogue-based teaching methods promote students' creative thinking and improve their mastery and application of sports terminology. Second, interactive teaching methods provide students with practical opportunities to improve their professional English skills through real-life applications. Khaydarova [23] pointed out that interactive methods, especially those simulating real professional scenarios, help sports students effectively master sports-related professional terminology and communication skills.

**Disadvantages:** However, interactive teaching methods also have certain limitations. First, large class sizes pose a common problem. In large class settings, it is difficult for teachers to ensure that every student fully participates in interactive activities, which can result in some students being neglected or insufficiently engaged in the learning process [2]. Second, students' language proficiency levels vary widely, and interactive teaching must consider individual differences. Cao [20] argued that teachers must balance the needs of students with varying language skills when designing interactive activities to prevent frustration or loss of confidence in some students.

Moreover, resource limitations are a significant challenge for interactive teaching methods. Zhang & Zhang [21] noted that the lack of appropriate teaching resources, especially digital resources for sports programs, can limit the effectiveness of interactive teaching.

### 5.2 Combining Theory with Practice

To better apply the theory of interactive teaching methods to practice, teachers need to adjust teaching content based on students' actual needs. Khaydarova [23] suggested that teachers can improve students' language application skills by introducing more realistic scenarios related to students' future careers, such as sports event press conferences or post-match interviews.

Additionally, using modern technology can enhance the effectiveness of interactive teaching methods. Chang et al. [17] found that combining AR technology with interactive teaching not only increased students' motivation but also significantly improved their performance in learning complex motor skills. By using AR technology, students can practice English communication skills in virtual scenarios, which is particularly suitable for sports English education.

Furthermore, course design should focus on the differentiated needs of students. Cao [20] recommended that teachers use tiered instruction and group discussions to ensure that students with varying language proficiency levels can participate effectively in interactive activities and benefit from them. Moreover, by assigning tasks of different difficulty levels or providing personalized guidance based on students' professional needs, teachers can help students at all levels achieve maximum learning outcomes.

### 5.3 Directions for Future Research

Most existing studies focus on the application of interactive teaching methods in general English instruction, with relatively few studies specifically addressing sports English education. Future research can further explore how to better integrate interactive teaching methods with the vocational skill needs of sports students. For example, studies can



examine how **interactive** teaching methods improve sports students' communication skills in international events and how multimedia tools and digital platforms can further optimize interactive teaching.

Additionally, existing studies mainly focus on small-scale experiments. Future research can conduct larger-scale empirical studies to verify the effectiveness of interactive teaching methods. Zhang & Zhang [21] suggested that future research explore the application of interactive teaching methods across different cultural backgrounds and how teaching strategies can be adjusted based on students' cultural contexts.

## 6 CONCLUSION

Through this study and a review of the literature, interactive teaching methods have demonstrated significant potential for improving professional English skills in sports programs. Grounded in SCT, interactive teaching methods effectively promote students' language proficiency, particularly in scenarios closely related to vocational applications, such as communication in sports events and the use of sports terminology. The study shows that interactive teaching, through collaboration, role-playing, and scenario simulation, helps students better master language skills in vocational contexts. Additionally, the application of ESP theory ensures that sports English education is more aligned with students' actual needs, with course design tailored to future professional scenarios, thereby improving students' communication skills and mastery of professional terminology.

Based on the theoretical analysis in this study, teachers can optimize sports English instruction, especially when resources or data are limited, by: **Task-Based Interactive Teaching:** By introducing real-life sports event scenarios such as press conferences and post-match interviews, teachers can create meaningful interactive tasks that help students practice language skills in realistic or simulated environments. This not only motivates students but also helps them develop the skills necessary for using English in their future careers. **Utilizing Modern Technology:** Despite resource limitations, teachers can leverage existing digital tools such as mobile applications, online interactive platforms, and augmented reality (AR) technology to provide a more engaging and immersive learning experience. Even simplified online tools can introduce simulated scenarios, enhancing students' language practice. **Differentiated Instruction:** Given that students' language proficiency levels vary, teachers can ensure all students participate effectively in interactive activities by using tiered instruction and group activities. Moreover, by assigning tasks of varying difficulty or providing personalized guidance based on students' professional needs, teachers can maximize learning outcomes for students of all levels.

While this study highlights the potential of interactive teaching methods in sports English education, there are some limitations. First, the conclusions are primarily based on a literature review, lacking large-scale empirical data. Future research can design large-scale experiments and surveys to further verify the effectiveness of interactive teaching methods across different educational contexts and explore their long-term impact on professional English skills development. Second, the application of interactive teaching methods in different cultural contexts requires further exploration. Since students from different cultural backgrounds face varying needs and challenges in language learning, future research can examine how interactive teaching methods can be adjusted to suit students' cultural and vocational backgrounds to ensure their broad applicability globally. In conclusion, interactive teaching methods hold significant promise for enhancing sports English education, but their effectiveness and feasibility still require further empirical validation and exploration.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# RESEARCH ON SUPPLIER SELECTION STRATEGY BASED ON AHP

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**Abstract:** As an important resource for enterprise production, the selection of suppliers is crucial. This paper takes Company Q as the research object, determines the supplier evaluation indexes of this company through expert scoring method and field research, and uses hierarchical analysis method to quantitatively analyse the supplier's indexes and determine the weight coefficients. From the four dimensions of having quality level, product price, delivery ability, service level and comprehensive ability, four suppliers are selected for evaluation, and the optimal supplier is selected based on the evaluation results.

**Keywords:** Supplier selection; Supplier management; Hierarchical analysis; Python

## 1 INTRODUCTION

With the increasingly fierce competition in the global market, manufacturers are increasingly aware of the importance of establishing close collaborative relationships with their suppliers. Especially in the framework of optimising resource allocation and enhancing economic efficiency, a superior supplier plays a pivotal role [1]. Through effective supplier management, these suppliers can continue to provide enterprises with stable and high-quality raw materials and components, thus achieving effective cost control. Such cost savings not only help to improve the operational efficiency of enterprises, but also significantly enhance their market competitiveness. Therefore, how to select the most suitable suppliers for the needs of enterprises has become one of the key factors for manufacturers to achieve competitive advantage.

Supplier selection is the core of supplier management. In domestic and international research, the focus is mainly on constructing evaluation indexes and selection methods for supplier selection, and fruitful results have been achieved in the research on the index system of supplier selection. Dickson GW [2], systematically identifies and refines 23 key indexes for assessing supplier capability, as shown in Table 1.

**Table 1** Vendor Selection Factors

Ordinal number	Factors	evaluations	Ordinal number	Factors	evaluations
1	Quality	RI	13	Management & Organisation	AI
2	Delivery	CI	14	Operational Control	AI
3	Historical benefits	CI	15	Maintenance Service	AI
4	Guarantee	CI	16	Attitude	AI
5	Production facilities	CI	17	Image	AI
6	Price	CI	18	Packaging Capability	AI
7	Technical capacity	CI	19	Labour relations record	AI
8	Financial status	CI	20	Geographic location	AI
9	Follow the quotation process	AI	21	Past business volume	AI
10	Communication system	AI	22	Personnel training support	AI
11	Reputation	AI	23	Business Reciprocity	SI
12	Business expectations	AI			

Note:EI is Extreme Importance;CI is Considerable Importance;AI is Average Importance;SI is slight Importance.

Since then, many researchers have rearranged and explored the priorities based on the criteria proposed by Dickson, further expanding and deepening the research scope of supplier management indicators and revealing more considerations that are crucial in the process of supplier selection and evaluation. Through extensive collection of literature, this study has sorted out the elements of supplier selection evaluation indexes that have attracted much attention at home and abroad, as shown in Table 2.

**Table 2** Indicator Elements for Supplier Selection

Authors	Indicator elements
Caddick[3]	Performance in previous years, quality level, production plan management system, purchase price
Marina Segura[4]	Research investment, product innovation capability, product development capability
HenkAkkermans[5]	Quality, delivery, technology, service, innovation ability, depth of co-operation
Tavana A B[6]	Corporate governance, management, staff team, production lines
Kumar[7]	Cost, delivery, location, quality, communication, management, performance, reputation
Singh[8]	Economy, product strength, organisation, green/environmental initiatives, supply risks, technology, social culture
Wang Xu Ping and Chen Ao[9]	Technology development, information technology level, business capability and after-sales service
Xu Qin and Yu Ge[10]	Enterprise creditworthiness, research capability, quality management capability, co-operation capability
Chen Jinglin[11]	Enterprise background and qualification, manufacturing capability, quality management, business management, customer service
Wu Yiwen[12]	Cost, quality, delivery, financial status, management level, service level, external environment
Yu Chunxia[13]	Price, quality, service level, environmental protection ability, supplier reputation

Analysic Hierarchy Process (AHP), a systematic method for multi-criteria decision-making problems, was proposed by Thomas L. Saaty, an American operations researcher, in the 1970s [14]. The core idea of the method lies in constructing a hierarchical model by decomposing a complex decision-making problem into several levels. Typically, the topmost layer represents the overall goal of the decision, the middle layer covers the guidelines or criteria affecting the decision, and the bottom layer is the options or measures that can be chosen. The elements of each layer are sequentially compared and weighted relative to the previous layer, resulting in a model that reflects the decision maker's preferences. In this model, the decision maker makes subjective judgements about the importance of each factor and expresses these preferences through a series of pairwise comparisons. Such pairwise comparisons are quantified in a mathematical form and used to calculate the relative weights or importance of the factors. This clear and structured approach to the multi-criteria decision-making problem enables qualitative judgements to be transformed into quantitative analyses, providing a framework for rational analysis by the decision maker.

This paper takes Company Q as the research object, and through analysing the company's suppliers, it is found that the company has the following supplier selection problems, firstly, the organisational structure of supplier selection is unreasonable; secondly, the existing evaluation indexes of supplier selection are single and confusing; and thirdly, the supplier selection process is not standardised. Therefore, this paper constructs a supplier evaluation model based on the hierarchical analysis method, hierarchises the complex problems, and proposes supplier selection and management strategies based on the evaluation results.

## 2 SUPPLIER SELECTION EVALUATION SYSTEM BASED ON AHP

### 2.1 Selection of the Components of the Indicator System

The supplier evaluation index system is an important basis used for comprehensive assessment and selection of suppliers [15]. Firstly, the main indicators affecting supplier selection are sorted out based on past literature analysis and actual research. Secondly, a supplier evaluation model containing the target layer, criterion layer and programme layer was constructed based on AHP. Among them, the criterion layer is subdivided into two layers, and the first-level indicators include quality level, product price, delivery capability, service level and comprehensive capability; the second-level indicators of the criterion layer involve 16 factors such as product qualification rate, and the specific indicators are shown in Figure 1.

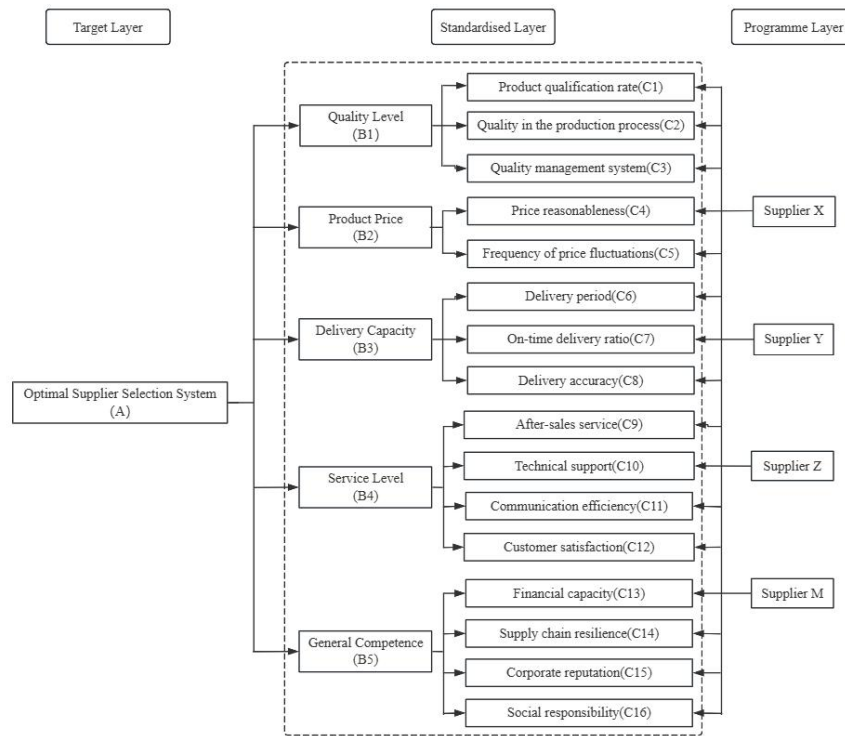


Figure 1 Supplier Evaluation System

(1) Quality level

In the supplier evaluation index system, quality level as a first-level indicator is usually used to assess the supplier's performance in product quality and production management. It consists of 3 parts, namely, product pass rate, quality management level and production process quality, and measures the supplier's quality control ability and reliability from different perspectives. Product pass rate refers to the proportion of products produced by the supplier that comply with quality standards and technical specifications. This indicator reflects the supplier's ability and stability to meet quality standards in the manufacturing process. A high product pass rate indicates that the supplier's production process, raw material control and quality inspection procedures are more stringent and effective, and that it is able to consistently provide high-quality products that meet customer requirements. Quality management system refers to a set of systematic management processes and control measures established by the supplier to ensure the quality of its products and services. Production process quality refers to the supplier in the actual production process, to ensure that the product meets the quality requirements of the specific control measures and quality assurance activities.

(2) Product price

Product price includes two secondary indicators, price reasonableness and price fluctuation frequency, from the rationality and stability of the two aspects of the supplier's pricing strategy and market adaptability. Price reasonableness refers to the competitiveness of the product price offered by the supplier within the market, and whether its pricing matches the product quality and service level. The frequency of price fluctuations reflects the stability and market responsiveness of the supplier's product price adjustment. The frequency and magnitude of price adjustments are assessed by analysing the supplier's record of price changes, the reasons for such changes and contractual terms and conditions. Lower frequency of price fluctuations usually indicates the stability of the supplier's pricing strategy, which helps enterprises to maintain the predictability and stability of procurement costs.

(3) Deliverability

Deliverability consists of three components: delivery period, on-time delivery rate and delivery accuracy. Delivery period refers to the supplier from the order to complete the delivery of the time required, a direct reflection of its production efficiency and logistics response speed, is an important factor in measuring its ability to perform. On-time delivery rate measures the supplier's ability to deliver products as planned within the specified time, reflecting its effective control of production planning and supply chain management, as well as its resilience and robustness in dealing with uncertainties. Delivery accuracy, on the other hand, focuses on the extent to which the supplier's requirements for quantity, quality and specifications are met in the delivery process, reflecting its ability to follow the terms of the contract and its integrity in the execution of the order.

(4) Service Level

The four secondary indicators of after-sales service, technical support, communication efficiency and customer satisfaction provide a comprehensive assessment of the level of supplier service. After-sales service refers to the supplier's maintenance, repair and service response capability after product delivery, reflecting its timely handling of customer issues and continuous support, which directly affects the customer's long-term experience of using the product. Technical support evaluates the supplier's ability to provide customers with technical guidance, training and consulting, as well as its professionalism in solving complex technical problems, reflecting its ability to provide value-added

services in technical cooperation. Communication Efficiency measures the speed and accuracy of the supplier's information transfer, problem feedback and decision-making response, representing its synergistic effect in business interactions. Customer satisfaction measures the overall evaluation of the supplier's service performance, reflecting the degree of customer recognition of the supplier's service quality.

(5) Comprehensive Capability

Supply chain resilience, financial capability, corporate reputation and social responsibility are selected as the secondary indicators of suppliers' comprehensive capability to comprehensively measure suppliers' overall strength and sustainable development capability from different dimensions. Supply chain resilience assesses suppliers' resilience and ability to continue supplying goods in response to market fluctuations, supply disruptions and other uncertainties, and ensures the stability of production in a complex environment. Financial capability measures the supplier's financial health and risk resistance, reflecting the reliability of its long-term performance and stable operation. Corporate reputation represents a supplier's credibility and image in the marketplace, affecting its credibility and value of cooperation in quality management, contract fulfilment and customer service. Social responsibility focuses on suppliers' performance in environmental protection, employee rights and social contribution, and ensures that the supply chain is in line with the company's sustainable development strategy and social expectations.

2.2 AHP Supplier Evaluation Indicator Mode

2.2.1 Constructing judgement matrices for selecting indicators

The role of constructing judgement matrix in AHP is to determine the relative importance between each evaluation index at the same level, and to provide a basis for subsequent weight calculation and decision-making. In this paper, we use the expert scoring method to assign values to the importance of each indicator, and adopt the 9-scale method to make two-by-two comparisons to quantitatively analyse the target layer and criterion layer respectively. The judgement matrix for the total target layer A is shown in Table 3.

Table 3 Judgement Matrix of the Criterion Layer for the Target Layer

A	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>
B <sub>1</sub>	1	5	3	7	4
B <sub>2</sub>	1/5	1	1/3	3	1/2
B <sub>3</sub>	1/3	3	1	5	2
B <sub>4</sub>	1/7	1/3	1/5	1	1/4
B <sub>5</sub>	1/4	2	1/2	4	1

According to the same method as the construction of the target layer matrix, for the criterion layer B can be listed separately as the judgement matrix of the quality level, product price, delivery capability, service level, and comprehensive capability indicators, as shown in Table 4-8.

Table 4 Judgement Matrix of Quality Level Indicators

B <sub>1</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
C <sub>1</sub>	1	3	5
C <sub>2</sub>	1/3	1	2
C <sub>3</sub>	1/5	1/2	1

Table 5 Judgement Matrix of Product Price Indicators

B <sub>2</sub>	C <sub>4</sub>	C <sub>5</sub>
C <sub>4</sub>	1	5
C <sub>5</sub>	1/5	1

Table 6 Judgement Matrix for Delivery Capacity Indicators

B <sub>3</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>
C <sub>6</sub>	1	1/4	1/5
C <sub>7</sub>	4	1	2
C <sub>8</sub>	5	1/2	1

Table 7 Judgement Matrix for Level-of-Service Indicators

B <sub>4</sub>	C <sub>9</sub>	C <sub>10</sub>	C <sub>11</sub>	C <sub>12</sub>
C <sub>9</sub>	1	2	4	1/3
C <sub>10</sub>	1/2	1	3	1/4
C <sub>11</sub>	1/4	1/3	1	1/5
C <sub>12</sub>	3	4	5	1

Table 8 Judgement Matrix for the Composite Capacity Indicator

B <sub>5</sub>	C <sub>13</sub>	C <sub>14</sub>	C <sub>15</sub>	C <sub>16</sub>
C <sub>13</sub>	1	3	5	7
C <sub>14</sub>	1/3	1	3	5

C <sub>15</sub>	1/5	1/3	1	3
C <sub>16</sub>	1/7	1/5	1/3	1

2.2.2 Calculation of the weights of the indicators and consistency test

(1) Weight calculation

Each indicator in the hierarchical structure has a different proportion of the target [16], and the weights can be used to quantify the relative importance of each evaluation indicator, by transforming the subjective judgement of experts or decision makers into objective data. Using python software, the eigenvalue decomposition of the judgement matrix is performed to calculate the maximum eigenvalues and their corresponding eigenvectors, and the eigenvectors are normalised to obtain the relative weights of each evaluation index.

The weight vectors of each matrix calculated by Python are as follows:

Vector of weights for the overall objective A:  $W_A = [0.484 \ 0.095 \ 0.229 \ 0.045 \ 0.147]^T$

Weight vector for quality level B<sub>1</sub>:  $W_{B_1} = [0.648 \ 0.230 \ 0.122]^T$

Weight vector for product price B<sub>2</sub>:  $W_{B_2} = [0.833 \ 0.167]^T$

Weight vector for delivery capability B<sub>3</sub>:  $W_{B_3} = [0.102 \ 0.532 \ 0.366]^T$

Weight vector of service level B<sub>4</sub>:  $W_{B_4} = [0.244 \ 0.153 \ 0.072 \ 0.531]^T$

Weight vector of overall capability B<sub>5</sub>:  $W_{B_5} = [0.558 \ 0.263 \ 0.122 \ 0.057]^T$

(2) Consistency test

Based on the maximum eigenvalue, the consistency index (CI) and consistency ratio (CR) are calculated to verify the consistency of the judgement matrix. If the consistency ratio is full  $CR < 0.1$ , the consistency of the judgement matrix can be considered reasonable to ensure the scientificity of the weight allocation. Python specific calculation results are shown in Table 9.

Table 9 Consistency Test Results

Matrix	$\lambda_{Max}$	CR	CI
A	5.138	0.035	0.031
B <sub>1</sub>	3.004	0.001	0.003
B <sub>2</sub>	2.000	0	0
B <sub>3</sub>	3.095	0.047	0.082
B <sub>4</sub>	4.119	0.040	0.044
B <sub>5</sub>	4.118	0.039	0.044

According to the values shown in Table 9, the CR value of each matrix is less than 0.1, so it passes the consistency test, proving that the judgement matrix of the designed optimal supplier selection model is set more reasonably. Accordingly, the evaluation system of the supplier selection model is obtained, as shown in Table 10.

Table 10 Overall Hierarchical Ordering

Overall Target	Level 1 indicators	Level 1 indicator weights	Level 2 indicators	Level 2 indicator weights	Portfolio weights	Arrange in order
Optimal Supplier Selection System (A)	Quality Level (B <sub>1</sub> )	0.484	Product qualification rate	0.648	0.314	1
			Quality in the production process	0.230	0.111	7
			Quality management system	0.122	0.059	2
	Product Price (B <sub>2</sub> )	0.095	Price reasonableness	0.833	0.079	8
			Frequency of price fluctuations	0.167	0.016	13
	Delivery Capacity (B <sub>3</sub> )	0.229	Delivery period	0.102	0.023	4
			On-time delivery ratio	0.532	0.122	3
			Delivery accuracy	0.366	0.084	14
	Service Level (B <sub>4</sub> )	0.045	After-sales service	0.244	0.011	12
			Technical support	0.153	0.007	6
			Communication efficiency	0.072	0.003	15
Customer satisfaction			0.531	0.024	5	
General Competence (B <sub>5</sub> )	0.147	Financial capacity	0.558	0.082	9	
		Supply chain resilience	0.263	0.039	16	
		Corporate reputation	0.122	0.018	10	
		Social responsibility	0.057	0.008	11	

3 EXAMPLE ANALYSES

Take the procurement of spare parts of Company Q as an example, its alternative suppliers are X, Y, Z and M4 companies. Setting, each indicator is full of 100 points, with 0 being the lowest score, each indicator is scored by the

evaluation group composed of company experts, and the evaluators can score the suppliers based on their actual performance and internal company information, and rank the scoring results. The assessment results should be specific, objective and fair, and can be explained and illustrated as necessary in the description of the assessment results[17]. The summary results of supplier scores are shown in Table 11.

**Table 11** Summary Results of Supplier Scores

Level 1 indicators	Level 2 indicators	Portfolio weights	Supplier X Score	Supplier Y Score	Supplier Z Score	Supplier M Score
Quality Level (B <sub>1</sub> )	Product qualification rate	0.314	85	90	80	85
	Quality in the production process	0.111	80	85	75	80
	Quality management system	0.059	75	80	70	75
Product Price (B <sub>2</sub> )	Price reasonableness	0.079	70	75	65	60
	Frequency of price fluctuations	0.016	65	70	60	80
Delivery Capacity (B <sub>3</sub> )	Delivery period	0.023	80	85	75	70
	On-time delivery ratio	0.122	85	90	80	70
	Delivery accuracy	0.084	90	80	85	80
Service Level (B <sub>4</sub> )	After-sales service	0.011	75	80	70	80
	Technical support	0.007	70	85	75	81
	Communication efficiency	0.003	80	80	65	75
	Customer satisfaction	0.024	85	90	75	75
General Competence (B <sub>5</sub> )	Financial capacity	0.082	70	85	75	77
	Supply chain resilience	0.039	75	80	70	80
	Corporate reputation	0.018	80	85	70	79
	Social responsibility	0.008	65	75	80	88
Totals			80.555	85.21	76.365	77.917
Sequence			2	1	4	3

According to the supplier evaluation system constructed in this paper and combined with the final score, it can be seen that: the score of Supplier X is 80.555, the score of Supplier Y is 85.21, the score of Supplier Z is 76.365, and the score of Supplier M is 77.917, so the optimal supplier for the procurement of spare parts in Company Q is Supplier Y, with which a strategic partnership can be formed to continually increase the trust in the cooperation. Therefore, the optimal supplier for Company Q's spare parts procurement is Supplier Y, which can form a strategic partnership with it and continuously increase cooperation trust. At the same time, it should also maintain a good trading relationship with Supplier X and Supplier M in order to prevent the occurrence of supply chain risk problems caused by special circumstances.

#### 4 CONCLUDE

This paper adopts the hierarchical analysis method to construct a supplier evaluation model, analyses the evaluation results of suppliers to help enterprises make supplier selection, and applies the model to Company Q as a real case to provide corresponding selection results and management strategies. It should be noted that each enterprise is in a different industry, and its specific situation has some differences, so the indicators in the model may not be applicable to all enterprises, and enterprises need to adjust the corresponding supplier evaluation indicators and strategies according to the actual situation.

#### COMPETING INTERESTS

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# DISCUSSION ON THE MECHANISM OF TCM PREVENTION AND TREATMENT OF "INFLAMMATION-CANCER" TRANSFORMATION

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**Abstract:** Cancer worldwide has a high incidence rate and a high case fatality rate, causing a serious disease burden on humans. It is of great significance to slow down the risk of cancer, to study the treatment of cancer and to clarify the target of cancer to improve the prognosis of patients with cancer. Chronic inflammation can lead to the occurrence of cancer, and the mechanism of inflammation leading to the occurrence and development of cancer is not very clear. Traditional Chinese medicine (TCM) can prevent inflammatory cancer transformation by inhibiting inflammatory reaction. This paper discusses the mechanism of TCM prevention and treatment of inflammatory cancer transformation, which is helpful to further explain the pharmacological effect of compound TCM prescriptions and active ingredients, in order to provide new ideas for the wider and more accurate application of TCM in clinical practice.

**Keywords:** Traditional Chinese medicine; Inflammation-cancer transformation; Epithelial-mesenchymal transition; Tumor-associated macrophages; Cancer stem cells

## 1 INTRODUCTION

Cancer worldwide has a high incidence rate and a high case fatality rate, resulting in a serious disease burden on humans. Cancer is also one of the main problems that threaten the health of our population. In recent years, the incidence and mortality of cancer in China have increased significantly [1]. It is of great significance to slow down the risk of cancer, study the therapeutic drugs to prevent and treat cancer, and clarify the relevant therapeutic targets to improve the prognosis of cancer patients.

Chronic inflammation can lead to the occurrence of cancer, such as colitis-associated colorectal cancer (CAC) caused by inflammatory bowel disease (IBD), liver inflammation can then induce liver cancer, and chronic inflammation of gastric mucosa can gradually lead to gastric cancer. However, at present, the mechanism of inflammation leading to the occurrence and development of cancer is not very clear. TCM is one of the important means of cancer treatment in China. Its therapeutic advantages are mainly reflected in regulating the inflammatory environment in tumor lesion tissues, regulating the influencing factors related to tumor inflammatory environment, so as to inhibit the growth of tumor cells and prevent the metastasis of cancer cells from blood tract and lymph. It is found that compound TCM prescriptions can prevent inflammatory cancer transformation by inhibiting inflammatory response, and its mechanism of action involves nuclear transcription factor- $\kappa$  B (NF- $\kappa$  B), Wnt /  $\beta$ -catenin and other signaling pathways [2]. This paper discusses the mechanism of TCM prevention and treatment of inflammatory cancer transformation, which is helpful to further explain the pharmacological effect of compound TCM prescriptions and active ingredients, in order to provide new ideas for the wider and more accurate application of TCM in clinical practice.

## 2 EPITHELIAL-MESENCHYMAL TRANSITION (EMT)

EMT is closely related to the occurrence and progression of malignant tumors, which is one of the important mechanisms of tumor invasion, metastasis and drug resistance. While TCM and active ingredients can act on tumor EMT to inhibit the proliferation, invasion and migration of cancer cells. Vimentin-mediated NLRP3 (NOD-, LRR- and pyrin domain- containing protein3) / Caspase-1 signaling, TGF- $\beta$ 1-induced EMT process, and the arachidonic acid-HETEs metabolic pathway activated by Gq proteins. All three pathways are involved in the regulation of inflammation, Vimentin, NLRP3, Caspase-1 are the core targets, Vimentin Is an important molecule linking the transformation of inflammatory carcinoma, It can participate in the regulation of tumor inflammation microenvironment through many aspects; NLRP3, Caspase-1 are involved in the formation of the NLRP3 inflammasome, The latter is one of the inflammasome with the largest number of ligands found to date, Its activation is not only able to promote the cleavage maturation of the inflammatory mediators pro-IL-1 $\beta$  and pro-IL-18, Be secreted outside the cell to exert various inflammatory effects, Can also induce Caspase-1-dependent cell pyroptosis, Make the cells die under inflammatory and stressed pathological conditions [3].NLRP3 inflammasome is involved in diverse inflammatory diseases. However, the endogenous regulatory mechanisms of NLRP3 inflammasome are still less defined.  $\beta$ -catenin, which is the central mediator of the canonical Wnt/ $\beta$ -catenin signaling, promotes NLRP3 inflammasome activation [4]. It was found that the TCM (composed of Astragalus, ganoderma lucidum and mountain mushroom) could inhibit EMT remodeling of tumor immune microenvironment [5]. Luo Yang found that Chutan Jiedu Decoction (composed of such as Dangshen, Atractylodes, and Poria) could regulate the expression of in EMT related proteins twist, fibronectin, and

Snail and vimentin. Qinghua Yichang Formula can inhibit the activation of NLRP3 inflammasome, reduce the activation of Caspase-1 and GSDMD proteins, regulate the immune balance, and reduce the expression of proinflammatory factors in [6-8]. Experimental studies have shown that  $\beta$ -lunivene can inhibit the proliferation, invasion and migration of lung cancer cells by inhibiting the EMT, stem cell-like properties and self-renewal ability of lung cancer cells. Taking the mechanism of EMT of TCM as the starting point, the paper aims to analyze the transcription level mechanism of the sequence evolution process of "inflammation-dysplasia-cancer" and the changes of key signaling pathways and molecules in the regulatory network of "inflammation-cancer", so as to provide a theoretical basis for the pathogenesis of the transformation and clinical diagnosis and treatment of inflammatory cancer.

### 3 TUMOR-ASSOCIATED MACROPHAGES (TAMS)

The tumor microenvironment has the largest proportion of numerous inflammatory cells with associated macrophages, with about 30%-50% [10]. Macrophages can be divided into two types: classically activated macrophages (M1) and selectively activated macrophages (M2). M1 can secrete immune regulatory factors such as IL-12, IFN and TNF- $\alpha$ , and make cytotoxic T lymphocytes in the tumor immune system; M2 is induced by IL-4 and IL-10 from the tumor environment, suppressing the anti-tumor immune response, accelerating the development of tumor, and directly or indirectly promoting cancer metastasis. According to relevant studies, Tumor-Associated Macrophages (TAMs) and their secreted factors are important components of the inflammatory microenvironment, and also play a very important role in the formation of tumor microenvironment and tumor development and development. The study found that [11], composed of astragalus, atractylodes, yunling and other Chinese medicine can reduce inflammatory necrosis of liver cells and liver cancer tissue gene expression, the main mechanism of prevention and treatment of liver cancer through downregulation of TGF- $\beta$ 1 induced liver cancer EMT process, Gq protein activation of arachidonic acid-HETEs metabolism pathway and Vimentin mediated NLRP3/Caspase-1 pathway, involved in the regulation of liver cancer inflammation microenvironment, inhibit the occurrence and development of liver cancer. The herbal prescription, the treatment of stress colitis, can affect JAK / STAT signaling pathway to reduce the serum inflammatory factors IL-4 and IL-10 in mice, promote the transformation of M2 macrophages into M1 macrophages, improve the tumor immune microenvironment under chronic stress, and inhibit the development of colorectal cancer [12].

### 4 NUCLEAR FACTOR $\kappa$ B (NF- $\kappa$ B)

NF- $\kappa$  B is the joint point, which can affect every link of cell homeostasis, thus triggering tumors. As the core protein of inflammatory response, in the process of inflammatory cancer transformation, the production mechanism and role of NF- $\kappa$  B are particularly important in the study of tumor inflammatory microenvironment. It is found that the compound TCM prescriptions coix seed can inhibit the release of pro-inflammatory factors and promote the release of anti-inflammatory factors by regulating NF- $\kappa$  B signaling pathway, so as to prevent the occurrence of colon cancer [13]. Paeonol, the active ingredient of TCM, can relieve CAC [14] by regulating the levels of TNF- $\alpha$ , IL-6, IL-1  $\beta$ , IL-10, STAT-3, and NF- $\kappa$ B p65 in mice.

### 5 CANCER STEM CELL (CSC)

CSC is key cells for tumor initiation and can lead to tumor malignancy and their recurrence, metastasis, as well as cancer cell heterogeneity. Wnt/ $\beta$ -catenin signaling pathway plays a very important role in EMT and is also one of the key points in maintaining CSC. The release of  $\beta$ -catenin from the cell membrane upon activation by specific ligands promotes the transcription of [15] from genes involved in the induction of the mesenchymal phenotype and maintenance of CSC.

It was found that the active components of TCM could inhibit the EMT process and CSC [16] simultaneously by inhibiting the PI3K / AKT, Notch1 and EZH 2 signaling pathways. According to TCM, CSC is the root cause of the "cancer toxicity" hidden in the cancer microenvironment, and CSC is in the tumor microenvironment of healthy qi deficiency, with both blood stasis and sputum [17]. "Cancer poison" and is closely related to tumor inflammatory microenvironment, the formation of "cancer poison" main pathological factors, blood stasis and tumor inflammatory microenvironment inflammatory factors, chemokines, tumor inflammatory microenvironment promote tumor metastasis EMT way also accord with the "cancer poison" phlegm stasis damp and heat through the pathogenic characteristics of [18].

At present, there are more and more studies on the role of compound TCM prescriptions and TCM active ingredients in regulating inflammatory factors and inhibiting CSC and related mechanisms. "inflammation-tumor stem cell" may become an important research direction for the prevention and treatment of the "inflammation-cancer" transformation in TCM.

### COMPETING INTERESTS

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# RESEARCH AND PRACTICE ON THE CONSTRUCTION OF A VIRTUAL SIMULATION TRAINING PLATFORM FOR INTELLIGENT MANUFACTURING

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**Abstract:** The construction of a demonstrative virtual simulation training base for vocational education is a crucial task aimed at adapting to national strategies and digital economic development requirements, serving the cultivation of composite technical and skilled talents in the new era, and promoting the high-quality development of vocational education in the context of the rapid development of new generation information technologies represented by artificial intelligence, big data 5G, virtual reality technology, etc. In recent years, the national and local governments have continuously strengthened policy guidance, invested a large amount of financial support, and actively transformed their thinking to implement digital transformation. Major universities have explored new ways to use virtual reality new technologies to reform traditional education and teaching models, solve the "three highs and three difficulties" problems in vocational education teaching and training courses, improve teaching quality, and cultivate skilled talents that meet the needs of enterprises. In this context, we have designed and developed an intelligent manufacturing virtual simulation training platform featuring digital twin capabilities, based on the existing intelligent manufacturing training base. This platform comprises one production line with four unit islands, enabling it to simulate the entire operation process of each unit island. Through practical teaching activities involving 436 students from various majors, the platform has proven to effectively enhance students' practical skills.

**Keywords:** Intelligent manufacturing; Virtual simulation; Digital twins; Training platform

## 1 INTRODUCTION

Following the introduction of the German Industry 4.0 and American Industrial Internet strategies, the Chinese government launched the "Made in China 2025" national development strategy in 2015. This strategy aims to foster innovative advancements in the manufacturing sector, facilitating the transition of traditional manufacturing towards intelligent manufacturing. Currently, intelligent manufacturing has emerged as the primary trend in global manufacturing development. The rapid advancements in new artificial intelligence technology, Internet technology, new generation information technology, new energy technology, material technology, and biotechnology constitute a significant aspect of this new era[1-4]. Vocational education bears the responsibility of providing talent reserves and capabilities for intelligent manufacturing. Intelligent simulation technology can effectively address the "three highs and three difficulties" in vocational education, namely the high cost, high workload, and high failure rates, as well as the difficulties in accessing resources and cost-effectiveness, thereby enhancing students' practical skills.

However, in practical teaching for intelligent manufacturing, the high investment cost of training equipment and the low utilization rate hinder the development of practical teaching. Therefore, it is particularly important to utilize virtual simulation training platforms for vocational education. The integration of virtual and real elements can effectively address the shortcomings of traditional training methods. On the one hand, it significantly reduces the investment cost of training equipment; on the other hand, by accurately simulating production data and mimicking real production environments, students are provided with practical operational experience that closely resembles reality. The use of a virtual simulation training platform not only greatly enhances students' practical skills but also effectively avoids potential risks in actual operations by creating a virtual laboratory that simulates high-risk experimental environments. The purpose of this study is to establish a virtual simulation training center for intelligent manufacturing.

## 2 CURRENT SITUATION AND EXISTING PROBLEMS

In the current field of education, virtual simulation training technology, as an innovative teaching method, is increasingly gaining attention for its application in professional courses. However, this technology has encountered multiple problems and challenges in its promotion and application.

### 2.1 Insufficient Integration of Technology and Professional Knowledge

The construction of virtual simulation training bases necessitates the integration of professional education and information technology. However, there are still instances where teachers exhibit a limited depth of technical application and rigid thinking, remaining at a superficial level of application[5, 6]. Consequently, teachers must enhance their learning and application of information technology, and integrate their professional knowledge to deeply apply it

in teaching practice. This can be facilitated through teacher training, interdisciplinary collaboration, and the development of teaching resources that integrate professional knowledge and technology.

## 2.2 Lack of Updates and Richness in Digital Educational Resources

With the rapid development of professional knowledge and technology, digital educational resources need to be updated in a timely manner to keep pace with the times. Therefore, it is necessary to promptly update digital teaching resources, encourage teachers and professionals to participate in the development of digital educational resources, continuously optimize teaching content, and ensure that it aligns with current professional needs.

## 2.3 The Innovation of Digital Teaching Applications is Not High

This is reflected not only in the high level of homogenization of resources, but also in the lack of innovation in teaching methods. Therefore, it is necessary to expand teachers' learning channels and keep abreast of new affairs and methods through various avenues. Additionally, strengthen communication between universities and the outside world, especially with universities and enterprises in regions with high education standards and developed economies, to avoid working in isolation.

## 3 CONSTRUCTION OF VIRTUAL SIMULATION TRAINING ENVIRONMENT

Based on "Internet Plus", we aim to create a new type of classroom that integrates both online and offline, virtual and real elements. Leveraging virtual factories and VR devices, we conduct immersive and collaborative interactive teaching to cultivate students' collaborative abilities. Utilizing various terminals such as PCs, mobile phones, and tablets, we implement "cloud-based" virtual simulation training teaching, enabling learners to conduct training anytime and anywhere, thereby fostering their self-learning abilities. In the virtual integrated training area, we first conduct virtual simulation, followed by real-world training, to promote the teaching of "virtual-real integration". By implementing "online and offline, virtual and real combination" teaching, we aim to advance the "classroom revolution" of deep integration and application of virtual and real elements. Simultaneously, we utilize virtual collaborative innovation zones to carry out innovation and entrepreneurship education, enriching the content of extracurricular teaching.

The virtual simulation training base, spanning over 2000 square meters, comprises two virtual simulation professional centers, one virtual simulation experience center, a virtual simulation innovation center, a virtual production line simulation center that integrates virtual and real elements, a virtual and real electromechanical joint debugging training unit, and seven virtual simulation training rooms.

### 3.1 Virtual Experience Center

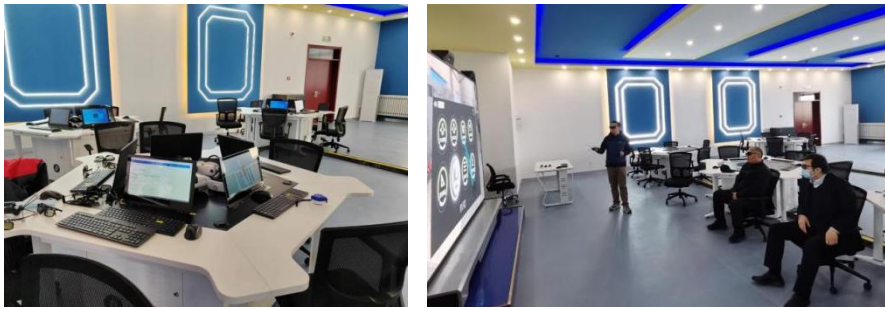
The virtual simulation experience center primarily relies on AR/VR/MR technologies to present the fundamental knowledge, basic skills, cultural science popularization, ideological and political courses, as well as innovative scientific research and teaching achievements in intelligent manufacturing through a variety of VR/AR/MR devices. Spanning 180 square meters, the center comprises immersive VR large-screen interactive display systems, 3D active stereoscopic glasses, virtual reality operation all-in-one devices (teacher-end), augmented reality (AR) software, AR cameras, smart interactive large screens, holographic fans, MR all-in-one devices, and other virtual simulation equipment. Within this environment, students can engage in immersive virtual simulation experiences as shown in Figure 1.



Figure 1 Virtual Experience Center

### 3.2 Virtual Simulation Professional Center

The indoor environment is equipped with immersive virtual simulation screens, 50 sets of virtual reality head-mounted display devices, 50 sets of graphics workstations, 10 sets of multifunctional training tables, VR helmet charging carts, and other accessories. Additionally, we have established hydraulic and pneumatic simulation training resources, simulation training resources such as Siemens PLC1200, a VR content resource management platform, multi-person collaborative adaptation software, cloud streaming software, and other related resources as shown in Figure 2.



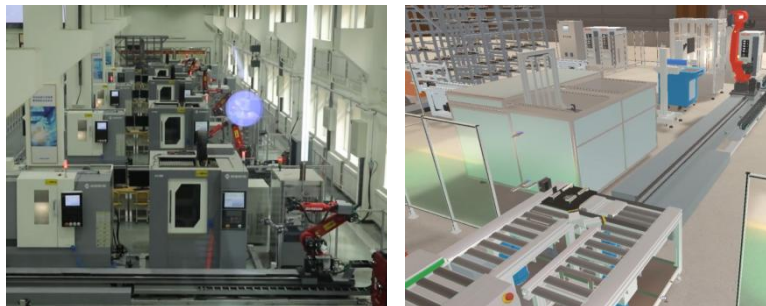
**Figure 2** Virtual Simulation Professional Center

### 3.3 Public Virtual Center

The public virtual center has established seven training rooms, namely the mold virtual design simulation training room, computer-aided design and manufacturing virtual simulation training room, intelligent production line virtual simulation training room, and numerical control technology virtual simulation training room, among others. These rooms are designed for extensive public virtual simulation training.

### 3.4 A System Combining Virtual and Real in Intelligent Manufacturing Based on Digital Twins

Leveraging the resource advantages of leading enterprises in the region, and focusing on the requirements of key job positions such as intelligent production line design, installation, commissioning, operation, maintenance, etc., the school-enterprise collaboration has jointly designed, developed, and constructed an intelligent manufacturing system. The system consists of four processing units, one cleaning and marking workstation, one logistics and warehousing system, ERP, MES, and central control system[7, 8]. At the same time, based on the principles of combining reality with virtuality, using virtuality to assist reality, and integrating virtuality with reality, simulation modeling of factory equipment is carried out with reference to physical objects. A large-scale precision instrument virtual simulation system is built using digital twin technology. Students repeatedly undergo virtual training, master the operation points, and then carry out practical training on the real system, solving the problems of complex large-scale systems, invisible interiors, and high training costs, as shown in Figure 3.



**Figure 3** A system that Combines Virtual and Real Elements in Intelligent Manufacturing

## 4 SCHOOL ENTERPRISE JOINT CONSTRUCTION BASE

The demonstration and leading digital professional construction, jointly established by schools and enterprises, has initiated digital transformation in 70% of key technical positions in emerging industries and intelligent manufacturing cooperative enterprises, resulting in a 5% year-on-year increase in employment in the high-end manufacturing industry[9]. Through collaboration with leading companies in the industry, we have implemented "order classes". Based on real-life teaching scenarios, we have adopted the "modern apprenticeship system" and "on-site engineer" training methods, fostering a unique talent cultivation model characterized by "employment upon enrollment, work upon learning, dual-subject training, and mentor-ship training".

To bridge the gap between curriculum and practice, we invite distinguished masters (craftsmen) from enterprises to participate in teaching reform, professional construction, and other related endeavors. We integrate enterprise production standards into talent cultivation practices and embed the spirit of craftsmanship into students' growth and development. This major has hired over 30 part-time teachers who are currently employed by enterprises. In recent years, teachers have participated in practical training in enterprises and have grown into technical experts at the provincial and municipal levels[10]. Consequently, the employment competitiveness and development potential of both teaching masters and students have significantly improved.

Based on a thorough analysis of the professional knowledge, skills, and qualities required for each position, both the school and enterprise establish professional talent training objectives. Incorporating the enterprise's typical work tasks and professional ability requirements, they collaboratively devise a practical and feasible professional talent training plan that aligns with job requirements. Together, they develop course content tailored to professional job groups and

refine a professional curriculum system based on typical work processes. They also jointly establish curriculum standards, job skill standards, and quality monitoring standards. Both parties will collaboratively integrate school and enterprise resources to create a multifunctional teaching and training base that fosters the comprehensive development of highly skilled talents.

## 5 THE CONSTRUCTION EFFECTIVENESS OF VIRTUAL SIMULATION CENTER

Intelligent manufacturing stands as the core driving force behind current industrial development, with virtual simulation technology emerging as a pivotal tool for nurturing talents in this field. To align with this trend, we have expedited the construction of the intelligent manufacturing virtual simulation training room. This training base not only facilitates virtual simulation of current intelligent manufacturing training, but also strives to leverage its unique strengths in multiple dimensions.

Through virtual simulation technology, we can effectively simulate real intelligent manufacturing environments, enabling students to engage in practical training operations without any risks. This simulated environment is not only safe, but also allows students to gain a deeper understanding of the manufacturing process and operational details of equipment. Additionally, virtual simulation technology can provide students with more practical operation opportunities, thereby helping them better master skills and improve their skill levels.

The establishment of virtual simulation training rooms has significantly reduced the cost of practical training. In traditional on-site training, high costs are often incurred due to equipment wear and material waste. Through virtual simulation technology, we can conduct practical training in a virtual environment, thereby avoiding these losses and wastes and effectively reducing costs.

Virtual simulation training, as an educational technology tool, provides learners with highly customized learning experiences. In a simulated environment, students can independently choose suitable training modules for operational exercises based on their own learning pace and preferences. This personalized learning method not only helps to stimulate learners' enthusiasm, but also promotes their deeper understanding and mastery of the required skills, thereby enhancing learning effectiveness.

The application of virtual simulation technology in the manufacturing industry can significantly enhance production efficiency and reduce operating costs, thereby strengthening the market competitiveness of enterprises. Leveraging this technology, manufacturers can perform high-precision simulations in product design and production process optimization, aiming to maximize efficiency and optimize costs.

## 6 CONCLUSION

Through the construction of a virtual simulation platform for intelligent manufacturing, the existing automation hardware equipment and production lines have undergone digital transformation. At the same time, digital course resources related to the intelligent manufacturing professional group have been developed, significantly improving the utilization of training hardware resources, enhancing the effectiveness of training teaching, while reducing education costs and saving maintenance and equipment update costs. Making the learning experience closer to real work scenarios in teaching not only helps students better adapt to future work environments, but also enriches practical experience, improves innovation ability, and achieves deep integration of industry, academia, research, and application.

## FUNDING

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## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# REVERSE MEASUREMENT AND MODELING OF MUDGUARD PROFILE BASED ON LASER SCANNING

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**Abstract:** Through studying the cultivation of high-skilled talents and the inheritance of craftsmanship spirit in vocational education, this research analyzes the vertical and horizontal transmission processes of craftsmanship spirit inheritance from a sociological perspective. The objective is to integrate and promote knowledge transmission, ability cultivation, and value shaping. By utilizing the "four factors", the craftsmanship spirit is coupled and internalized in the process of cultivating high-skilled talents. Through the "three transformations" of the craftsmanship spirit, the problem of precise matching between the "three embeddings" of the spirit of craftsmanship and the "three integrations" of skill cultivation has been solved. Relying on four key areas, the difficulties in skill cultivation and the inheritance of the spirit of craftsmanship have been addressed, gradually forming a "composite four-factor resonance, three-in-one" ecological model for the cultivation of high-skilled talents. This provides a theoretical basis and typical examples for the cultivation of high-skilled talents and the inheritance of the spirit of craftsmanship.

**Keywords:** 3D detection; Reverse design; 3D Scanning

## 1 INTRODUCTION

A mudguard is a plate-shaped object fixed to the rear frame of a car wheel, typically crafted from high-quality rubber or high-strength plastic. Mudguards are commonly installed behind the wheels of vehicles, with materials commonly being plastic or rubber. The primary function of a mudguard is to prevent dust and dirt thrown up by the wheels from splashing onto the vehicle or the driver, which can detract from the vehicle's appearance and protect related car parts from being affected or rusting. Additionally, mudguards can prevent stones and other objects carried in the wheels from being thrown onto the vehicle or the driver, thus avoiding damage to the paint or injury to the driver[1]. The mudguard structure features a complex curved shape. For forward design, designers must create a model from scratch, which not only prolongs the production cycle but also increases the corresponding production cost. Therefore, the challenge lies in finding technical solutions that can facilitate the creation of a precise 3D model for subsequent shape inspection, defect repair, or innovative modifications to the mudguard, which has become a significant hurdle nowadays.

In recent years, computer science and technology have rapidly advanced, with reverse design emerging as a standout practice in the industry and garnering significant attention. Reverse technology has the capability to transform existing parts into three-dimensional digital models, thereby not only enhancing design efficiency but also significantly cutting down production costs, addressing issues inherent in forward design[2]. Utilizing reverse design technology, we can swiftly acquire three-dimensional digital models of intricately structured parts, offering a precise solution for subsequent innovative modifications and precision testing of these parts.

This paper utilizes a 3D laser scanner to scan the mudguard, acquiring 3D point cloud data. This data is then modeled using reverse engineering software, resulting in a 3D digital model of the mudguard. Subsequently, a precision comparison analysis is conducted between the 3D digital model obtained from reverse design and the point cloud data obtained from 3D scanning, to assess whether the 3D digital model meets the design requirements. This provides precise and effective data for future secondary innovation and repair of mudguards.

## 2 PRINCIPLE OF LASER 3D SCANNING

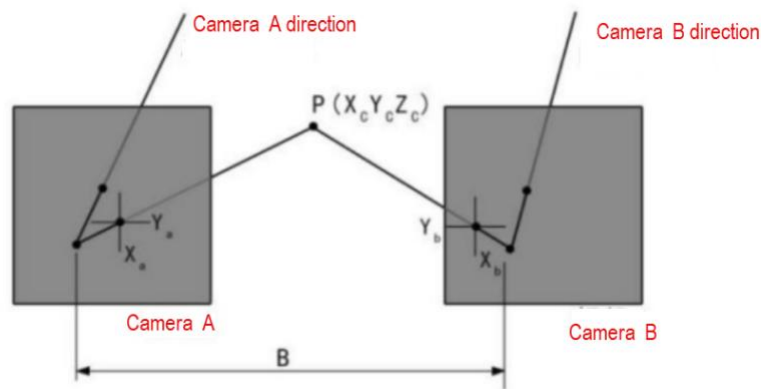
The acquisition of 3D point cloud data marks the initial step in reverse engineering. Point cloud data acquisition devices are categorized into contact and non-contact types. Commonly used contact devices include coordinate measuring devices manufactured by companies like Zeiss, ZK, and DEA[3]. Non-contact devices primarily consist of optical measurement devices, which prove to be more convenient when acquiring data from complex curved parts. The most frequently used non-contact devices are 3D scanners produced by companies such as Creaform, GOM, and SCANTECH.

In this chapter, the PRINCE775 handheld laser scanner provided by Sihua Technology (Hangzhou) Co., Ltd. is utilized to gather point cloud data of mudguards. Figure 1 depicts the PRINCE775 handheld laser 3D scanner. Its core technology lies in the 3D laser measurement method. The scanner primarily consists of two cameras and a set of laser emitters. It employs the binocular vision principle to acquire three-dimensional point clouds in space. During operation, it utilizes reflective markers affixed to the surface of the part to be scanned for positioning. The laser emitter emits light to illuminate the surface of the component, while two manufacturer-calibrated cameras capture the reflected light. Part shape data is then obtained through calculation.



**Figure 1** PRINCE775 Handheld Laser 3d Scanner

The principle of binocular vision is a crucial form of visual recognition, primarily utilizing multiple images to compute geometric information and derive corresponding positional data [4]. This principle typically involves two cameras capturing images simultaneously from different angles, resulting in two images. Using the disparity principle, the three-dimensional geometric information of the measured point is calculated, ultimately presenting a comprehensive set of three-dimensional data. Figure 2 illustrates a relatively simple schematic diagram of binocular vision imaging, featuring cameras A and B. B represents the distance between the center points of the projection directions of the two cameras, known as the baseline distance.



**Figure 2** Schematic Diagram of Binocular Vision

As shown in the figure, assuming point P is the measured point, the imaging point coordinates of camera A are  $P_a=(X_a, Y_b)$ , and those of camera B are  $P_b=(X_b, Y_b)$ . If the two cameras are on the same plane, the coordinates of point P in the Y direction will be the same, that is,  $Y_a=Y_b=Y$ . According to the principles of trigonometry, it can be concluded that:

$$\begin{cases} X_a = f \frac{X_c}{Z_c} \\ X_b = f \frac{(X_c - B)}{Z_c} \\ Y = f \frac{Y_c}{Z_c} \end{cases}$$

Parallax is defined as the deviation of the same point in the X direction of the left and right cameras, denoted as  $\text{Disparity} = X_a - X_b$ . Therefore, the position of point P in the left camera coordinate system can be represented as [5]:

$$\begin{cases} X_c = \frac{B \cdot X_a}{\text{Disparity}} \\ Y_c = \frac{B \cdot Y}{\text{Disparity}} \\ Z_c = \frac{B \cdot f}{\text{Disparity}} \end{cases}$$

Laser-based 3D scanners are easy to operate, feature fast acquisition speeds, and deliver high data accuracy. They can output files in formats such as STL, ASC, and OBJ, and can also be directly opened and edited in other reverse engineering software. As a new type of fast and convenient measuring device, handheld laser 3D scanners are widely used in practical production, mold inspection, aerospace, and medical and healthcare fields. Table 1 presents the main technical parameters of the PRINCE775 handheld laser 3D scanner.

**Table 1** Technical Parameters of PRINCE775 Handheld Laser 3D Scanner

Model	PRINCE775	
Scanning Mode	R Standard Scanning Mode	B-Ultrasound Fine Scanning Mode
Laser form	14+1	5
Accuracy		0.030mm
Scanning rate	480000 measurements per second	320000 measurements per second
Camera frame rate	60fps	120fps
Maximum scanning surface width	275mm×250mm	200mm×200mm
Resolution	0.050mm	0.020mm
Volume accuracy	0.020mm+0.060mm/m	0.010mm+0.060mm/m
Reference distance	300mm	150mm
Depth of Field	250mm	100mm
Output formats include	.stl,.ply,.obj,.igs,.wrl,.xyz,.dae,.fbx,.asc, etc	

### 3 PREPARATORY WORK FOR DATA COLLECTION

To obtain high-quality 3D point cloud data, some preparatory work must be carried out prior to scanning. Paste marking points: Given that the mudguard's shape primarily consists of curved surfaces and there are no scanning blind spots, 3D scanning of the mudguard is relatively straightforward. To facilitate automatic stitching of the mudguard point cloud data during the acquisition process by the 3D scanner, it is necessary to paste an appropriate number of marking points on the mudguard surface. This enables the scanning device to swiftly and accurately stitch the point cloud data during the acquisition process. Marking points serve as crucial reference objects for assisting the 3D scanner in stitching. Improper pasting can prevent the scanned data from accurately representing the true shape and may also result in the loss of important features. Therefore, during the process of pasting marking points, the following points should be noted: Marking points should be pasted on a relatively flat surface of the object and should avoid the boundary of the zero point. Marking points cannot be pasted in a straight line, and the pasting effect should not be symmetrical. The number of transitional marker points should be at least three, but due to the shape and scanning angle of the marker points, there are a few that cannot be recognized. Therefore, it is recommended to increase the number of marker points pasted as much as possible, usually at least five [6]. The pasted marking points should ensure a smooth transition during the scanning process to complete scanning from various angles, and should be evenly pasted in all directions. As shown in Figure 3, the mudguard model is pasted with complete marking points.



**Figure 3** Model of Mudguard with Complete Marked Points Pasted

Scanner calibration: Laser 3D scanners, as high-precision measuring devices, necessitate precision calibration, also termed as calibration, prior to use to enhance the performance of 3D scanning operations. Calibration of the 3D scanner is imperative in the following scenarios: 1. After long-distance transportation or changes in the scanning environment. When the scanning quality is subpar. When the scanning data cannot be stitched together. The handheld laser 3D scanner utilized in this article comes equipped with a corresponding calibration board provided by the manufacturer. Following the computer's prompts, calibration can be accomplished within half a minute after proficient use.

Scanning parameter settings: During the 3D scanning process, there are two parameters that directly affect the scanning speed and quality, namely "resolution" and "exposure value". Resolution will affect the level of detail presented in scanning. Taking mudguards as an example, there are no small features on the surface of mudguards, and the minimum rounded corner is around 1mm. Therefore, the resolution can be set at around 0.5, but the smaller the parameter set, the slower the scanning speed. Therefore, the resolution is set to 0.7mm. The exposure value affects the brightness of the

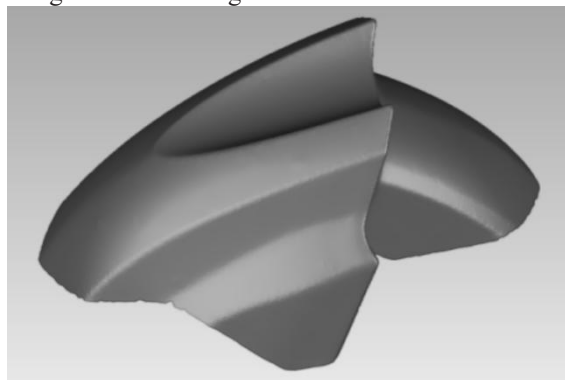
projected laser, which depends on the color and reflectivity of the scanned part surface. Taking the mudguard as an example, it is made of white plastic injection molded with a moderate smoothness and no obvious reflectivity. Therefore, the exposure value can be set to "2".

#### 4 THREE DIMENSIONAL DATA ACQUISITION

The collection of 3D point cloud data serves as the initial step in reverse engineering, with the quality of the point cloud obtained from 3D scanning directly impacting the quality of subsequent reverse modeling and accuracy inspection. This paper employs a handheld laser scanner to gather data on the outer surface of mudguards. During the 3D scanning process, the scanner locates marker points affixed to the object's surface, completes the stitching between frames, and thereby acquires comprehensive 3D point cloud data of the mudguard. Points to consider during the 3D scanning operation include: the scanning environment should not be excessively bright, as this could interfere with the generation of point clouds in high-light areas on the object's surface, potentially resulting in the formation of holes; During the scanning process, the 3D scanner must move at a steady and slow pace to prevent shaking, as this can introduce noise and affect the scanning outcome, thereby increasing the workload of post-processing; If the computer fails to adjust to the corresponding angle when the scanner is moved during the scanning process, it is necessary to consider whether the placement of marker points is improper or whether the scanner requires recalibration. Figure 4 displays the final 3D point cloud data of the mudguard. The scanned data can be optimized in scanning software, including hole filling, noise reduction, and smoothing. Ultimately, the point cloud data is encapsulated to produce a triangular surface model. This software supports the generation of STL format files, thus the scanned 3D data is saved in STL format to prepare for future reverse modeling.

#### 5 POINT CLOUD DATA PROCESSING

Laser scanners, as optical devices, can scan larger objects to obtain a large number of data points in a shorter time, up to tens of thousands per second, and can generate more precise digital information of the scanned parts. However, the data scale of laser 3D scanning point cloud data is relatively large, and it may be interfered by some similar features during the 3D scanning process, resulting in an increase in the number of scanned point clouds and an increase in computer computation [7]. Therefore, it is necessary to simplify and optimize the point cloud while ensuring its accuracy. Because laser scanners are optical devices, they are affected by environmental light, scanner operating distance, and the degree of reflection on the surface of the object being measured during operation, which can reduce the quality of 3D point cloud data. Sharp spikes or floating points on their surface can also form voids on the surface of the point cloud data. In some features with deep holes or subtle gaps, laser cannot penetrate them or cannot recognize the reflected light, resulting in holes caused by data loss. To achieve high-quality and efficient reverse modeling, it is necessary to optimize the 3D point cloud data and ultimately generate a complete and flawless triangular mesh model. Therefore, it is necessary to optimize the 3D point cloud data to achieve the requirements of removing redundant features, filling holes, and smoothing surfaces. Data processing mainly includes point cloud smoothing, hole filling, point cloud simplification, and coordinate alignment [8]. Due to the large amount of data generated by 3D laser scanners during data acquisition, some unnecessary noise points may be generated. It is necessary to improve the quality of point clouds by using methods such as smoothing point clouds and reducing noise. Mainly using computers to filter out noise points, all point clouds are filtered and ultimately optimized shown in Figure 4,. The commonly used filtering methods include standard Gaussian filtering, median filtering, and average filtering. Gaussian filtering can ensure the shape of the original data as much as possible, with minimal impact on its shape. Median filtering can remove features that resemble spikes generated. The average filtering takes the average value between the two methods.



**Figure 4** Mudguard Scanning Data

#### 6 SURFACE RECONSTRUCTION OF MUDGUARD

##### 6.1 Import Data

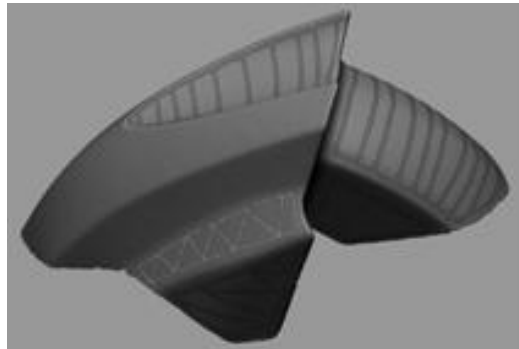
Drag and drop the model data directly into the Geomagic Design X window to open the model.

## 6.2 Coordinate Alignment

Since the mudguard is symmetrical, the symmetrical plane can be used as one direction of the coordinate system. Create a plane that approximates the mirror plane, and automatically calculate a more precise mirror plane using the mirror method within the additional plane method. Extract the contour lines of the data on this plane, select one line as the other direction of the coordinate system. With a plane and a line segment satisfying the alignment requirements, the coordinate alignment is completed.

## 6.3 Domain Segmentation

Firstly, it is essential to establish the reverse modeling approach. Given the numerous mudguard surfaces, we primarily utilize surface fitting and lofting guides to manually segment the model into distinct domains based on varying curvatures. The segmentation results are illustrated in Figure 5.

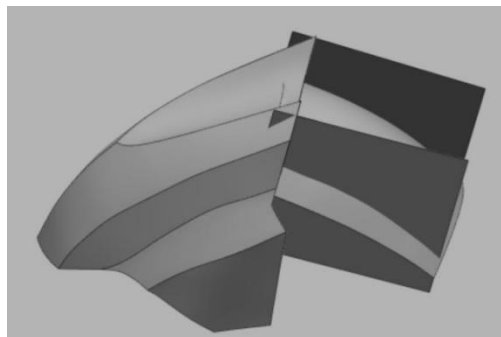


**Figure 5** Fender Domain Segmentation

## 6.4 Surface Creation

Curves serve as the foundation for surface construction. In reverse engineering, splines are typically adjusted via interpolation or approximation, followed by the generation of surfaces through scanning, stretching, sampling, and other techniques. Curves determined by interpolation must pass through all measured data points, ensuring zero error between the curve and the data points. However, with a large amount of data and noise points, there may be too many curve control points, making the interpolation results uncertain. The approximation method tolerates some errors and permits the adjustment of the number of control points. The distance between the curve and the data points is calculated using the least squares method, and the control points are adjusted to meet the error requirements. Since the parts are laser scanned, and the volume of point cloud data is substantial, the contour curve of the machined assembly surface is adjusted through interpolation, while the surface contour curve is approximately adjusted. Set and limit the shape, size, and position of key curves, and modify other curves accordingly.

The front section of the mudguard is completed using the layout command. Firstly, 10 planes corresponding to the normal direction are created according to the surface shape. The corresponding contour lines are extracted from each plane, and a contour line sketch is established. The 10 contour lines are surveyed using the surface layout command to obtain the surface shape. Then, the domain surface is created using the layout guide, patch fitting, and other commands. The surface creation result is shown in Figure 6.

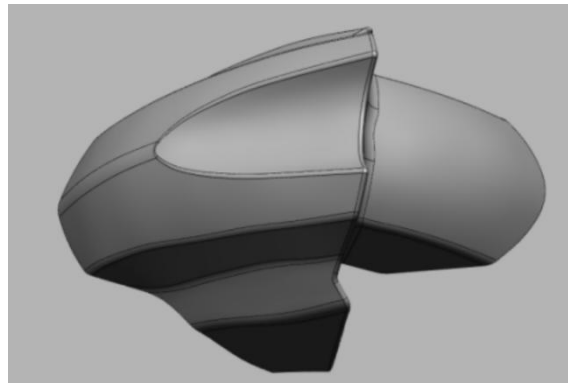


**Figure 6** Surface Fitting Results

## 6.5 Detail Processing

Crop the existing surface shapes together, use the mirror command to copy the surface shape on the other side, and complete the creation of all surfaces. Using the thickness command, assign thickness to the surfaces, transforming the

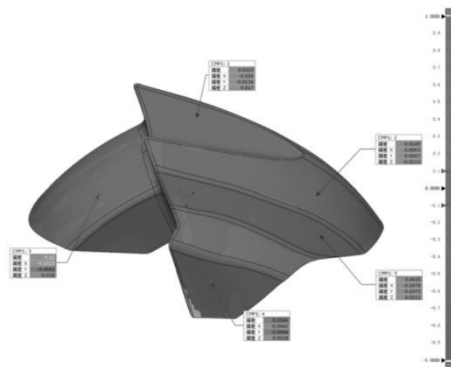
model into a solid state. Finally, round the edges to complete the reverse modeling. The final effect is shown in Figure 7.



**Figure 7** Reverse Design Result

## 7 ACCURACY ANALYSIS OF MUDGUARD SURFACE

Utilize Geomagic Control X software to compare and analyze the CAD model obtained from reverse modeling with the point cloud data acquired from 3D scanning. Initially, coordinate alignment is conducted. Since both datasets are exported from the same coordinates within Geomagic Design X software, they are already aligned upon import, eliminating the need for further manipulation. Subsequently, a 3D comparison is carried out, resulting in a 3D comparative chromatogram that facilitates precise accuracy identification through the colors displayed on the model. Employ 2D comparison, comparison points, and other pertinent functions to produce detailed data. Ultimately, a comprehensive comparative report is generated. According to the report, the maximum error between the reverse CAD model and the 3D point cloud data stands at 0.12mm, while the minimum error is 0.01mm. The comprehensive comparative chromatogram is illustrated in Figure 8. The overall reverse modeling accuracy of the mudguard is high, and the quality of the parting line and surface is reasonable and reliable, albeit with significant deviations at certain sharp corners or grooves.



**Figure 8** Comparison Chromatogram of Accuracy

Typically, the critical dimensions of laser scanning point cloud data models and coordinate measurement inverse models are rounded off based on the measurement results. Since most crucial design geometric parameters are integers, the rounding process aims to preserve the original dimensions and design concept while minimizing errors in the reverse modeling results. However, due to measurement errors from both measurement methods and discrepancies in geometric dimensions when modeling non-significant areas, the maximum local deviation reaches 0.12mm. After undergoing comprehensive verification and iterative testing, it has been confirmed that the accuracy of the reconstructed model meets the precision requirements for mudguard design.

## 8 CONCLUSION

By utilizing a handheld laser 3D scanner to gather 3D data of the mudguard, and subsequently employing reverse modeling software to conduct feature domain segmentation, extract spline curves, loft surfaces, trim surfaces, and assign thickness to the 3D point cloud data, we have successfully reverse-modeled the mudguard and derived a CAD model. We then compared and analyzed the CAD model obtained from reverse design with the 3D point cloud data gathered from scanning, completing accuracy testing. Ultimately, we determined that the maximum deviation was 0.12mm, satisfying the design requirements. This experiment underscores that the 3D data acquisition and reverse reconstruction modeling approach utilizing handheld laser 3D scanners offers a highly efficient and precise reverse

design method for curved components. This method facilitates innovative design, repair, and enhancement of products in subsequent stages, significantly reducing the research and development cycle.

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## COMPETING INTERESTS

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# RESEARCH ON THE LEGAL GUARANTEE FOR THE PROTECTION OF RURAL ECOLOGICAL ENVIRONMENT AND RURAL ECONOMIC DEVELOPMENT IN CHINA UNDER THE BACKGROUND OF RURAL REVITALIZATION - FROM THE PERSPECTIVE OF LAND DEVELOPMENT AND INDUSTRIAL ADVANCEMENT

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**Abstract:** Achieving a balance between rural ecological environment protection and rural economic development poses a formidable challenge. Neither sacrificing rural ecological integrity solely for economic growth nor prioritizing environmental conservation at the expense of rural residents' economic aspirations represents a viable solution. Building upon the eradication of absolute poverty in 2020, China has introduced the Rural Revitalization Strategy, leveraging legal instruments to pursue harmonious development between rural economic prosperity and environmental sustainability. This strategic approach offers valuable insights and experiences for other nations grappling with the dual challenges of rural economic development and environmental conservation.

**Keywords:** Rural revitalization strategy; Rural ecological environment protection; Rural economic development

## 1 INTRODUCTION

In the wake of rapid urbanization and industrialization, China's rural areas have faced numerous challenges, including ecological degradation and economic stagnation. The implementation of rural revitalization strategies aims to address these issues by fostering sustainable development that harmoniously integrates economic growth with environmental conservation. The research on the legal framework that safeguards both environmental protection and economic advancement in rural China is crucial, not only for domestic purposes but also for its international significance. As China, with its vast rural population and diverse agro-ecological systems, offers a unique case study, its experiences and lessons can serve as valuable references for other countries, particularly those in developing economies, striving to balance rural development with ecological preservation. Understanding the legal mechanisms that facilitate this balance is imperative for global efforts towards sustainable rural transformation.

This paper endeavors to delve into the current state of legal safeguards governing rural ecological environment protection and economic development in China amidst the backdrop of rural revitalization. Furthermore, the paper endeavors to formulate practical recommendations aimed at enhancing the effectiveness of these legal guarantees, thereby contributing to the holistic and sustainable revitalization of China's rural areas. By doing so, it hopes to offer insights that can be adapted or inspired by other nations embarking on similar rural development trajectories.

## 2 OVERVIEW OF CHINA'S RURAL REVITALIZATION STRATEGY AND RURAL ECOLOGICAL ENVIRONMENT

### 2.1 Origin of China's Rural Revitalization Strategy

China's Rural Revitalization Strategy emerged as a pivotal component of the country's overall development blueprint, building upon the profound achievements of the Targeted Poverty Alleviation Strategy. Initiated in 2013, the Targeted Poverty Alleviation Strategy revolutionized poverty eradication efforts by adopting a precision approach, ensuring that resources and policies were tailored to the unique needs of impoverished households and regions. This strategy not only lifted millions out of absolute poverty but also laid a solid foundation for further rural development.

The Rural Revitalization Strategy, as a logical extension of the poverty alleviation efforts, aims to address the lingering issues of imbalanced and insufficient rural development, striving for a holistic and sustainable rural transformation. It integrates and expands upon the precision principles of targeted poverty alleviation, focusing on long-term strategies for economic growth, social progress, and ecological conservation. By doing so, the strategy seeks to bridge the urban-rural divide and foster a more equitable and inclusive development path.

### 2.2 Core Essentials of China's Rural Revitalization Strategy

The core essentials of China's Rural Revitalization Strategy encompass multifaceted aspects aimed at revitalizing rural areas comprehensively. These include:

**Industrial Prosperity:** Fostering diversified and innovative rural industries to boost agricultural productivity and create new economic opportunities.

**Ecological Livability:** Enhancing rural ecological environments through sustainable agricultural practices and eco-friendly infrastructure, ensuring a harmonious coexistence between humans and nature.

**Cultural Vitality:** Preserving and promoting rural cultural heritage, fostering a vibrant rural culture that enriches the spiritual lives of residents.

**Effective Governance:** Strengthening rural governance systems to ensure efficient and democratic decision-making processes, promoting social stability and harmony.

**Prosperous Living Standards:** Increasing rural incomes and improving living conditions, ensuring that all rural residents share in the fruits of development.

### 2.3 Concept of China's Rural Ecological Environment

The rural ecological environment in China refers to the intricate system encompassing both natural and human-made elements that support rural life and economic activities. It comprises fertile farmland, lush forests, clean water bodies, as well as the infrastructure and lifestyles that characterize rural communities. This environment serves as the bedrock for agricultural production and rural residents' wellbeing, underpinning the sustainability of rural economies and societies.

### 2.4 Current State and Challenges of China's Rural Ecological Environment

Despite significant improvements, China's rural ecological environment continues to face numerous challenges. The current state and challenges can be summarized as follows:

**Pollution Intensification:** Agricultural intensification, characterized by heavy use of fertilizers and pesticides, has led to soil and water pollution. Additionally, inadequate waste management systems result in untreated sewage and solid waste disposal, exacerbating environmental degradation.

**Ecological Degradation:** Overexploitation of natural resources, such as deforestation, overgrazing, and unsustainable farming practices, has caused severe ecological degradation, threatening biodiversity and ecosystem services.

**Infrastructure Deficiencies:** Rural areas often lag behind in terms of environmental infrastructure, including wastewater treatment facilities and solid waste management systems. This infrastructure gap hinders effective pollution control and environmental management.

**Legal and Regulatory Gaps:** While progress has been made in environmental legislation, enforcement in rural areas remains weak, with gaps in the legal framework and inadequate regulatory oversight.

**Limited Public Awareness:** A lack of environmental awareness among rural residents, coupled with inadequate education and outreach programs, hampers their ability to contribute to environmental conservation efforts.

## 3 ANALYSIS OF THE RELATIONSHIP BETWEEN RURAL ECONOMIC DEVELOPMENT AND RURAL ECOLOGICAL ENVIRONMENTAL PROTECTION IN CHINA

### 3.1 The Mutual Promotion Relationship between Rural Economic Development and Rural Ecological Environmental Protection in China

The intricate interplay between rural economic development and rural ecological environmental protection in China presents a dynamic balance that underscores their inherent synergy. In the Chinese context, the concept of "Lucid waters and lush mountains are invaluable assets" encapsulates the essence of this mutual promotion. It emphasizes that a healthy environment is not only essential for human well-being but also a source of economic prosperity. This philosophy guides policymaking, encouraging a shift towards green and low-carbon development paths that prioritize both economic growth and environmental sustainability. In China, this Mutual Promotion Relationship is manifested as follows:

Firstly, rural economic development provides the necessary financial resources and technological advancements that enable more effective ecological environmental protection measures. As rural economies prosper, governments and communities have greater capacity to invest in environmental infrastructure, such as wastewater treatment facilities, solid waste management systems, and renewable energy projects. These investments mitigate pollution, conserve natural resources, and enhance the overall resilience of ecosystems. For instance, the adoption of modern agricultural techniques reduces the reliance on chemical fertilizers and pesticides, thereby diminishing soil and water contamination. Secondly, a healthy rural ecosystem offers a myriad of ecological services that directly contribute to rural economic development. Clean water, fertile soil, and diverse biodiversity are essential resources for agriculture, tourism, and other sectors. The preservation of these resources attracts eco-tourism, which in turn generates employment opportunities, boosts local economies, and increases incomes for rural households. Additionally, the provision of ecosystem services, such as pollination, pest control, and climate regulation, enhances agricultural productivity and reduces the need for external inputs, further fueling economic growth.

Furthermore, innovation and technological advancements play a pivotal role in fostering this mutual promotion relationship. For example, precision agriculture techniques utilize data analytics and sensor technology to optimize resource use, minimizing waste and environmental degradation. Similarly, renewable energy sources like solar and

wind power reduce dependence on fossil fuels, decreasing greenhouse gas emissions and promoting clean energy development.

### **3.2 The Potential Conflict Relationship between Rural Economic Development and Rural Ecological Environmental Protection in China**

While the mutual promotion relationship between rural economic development and rural ecological environmental protection is paramount, there also exists the potential for conflicts and trade-offs.

Firstly, one of the primary sources of conflict arises from resource scarcity and the tendency towards overexploitation. As rural economies grow, there is an increased demand for land, water, and other natural resources. This often leads to intensive farming practices, unsustainable land use, and excessive extraction of natural resources, causing soil degradation, water pollution, and biodiversity loss. The competition between economic development and environmental conservation becomes more pronounced, forcing difficult decisions and compromises.

Secondly, the push for rural industrialization and urbanization also contributes to potential conflicts. Industrial activities, particularly those without proper environmental safeguards, can generate significant pollution, including air and water contamination, as well as solid waste. This not only degrades the environment but also threatens public health and reduces the quality of life for rural residents. Balancing industrial growth with environmental protection becomes a significant challenge.

Thirdly, another dimension of conflict lies in the tension between short-term economic gains and long-term environmental sustainability. In many cases, immediate economic benefits from resource exploitation or industrial expansion may seem attractive, but they often come at the cost of long-term ecological damage. This creates a dilemma for policymakers and communities, who must weigh the short-term benefits against the potential long-term consequences.

Fourthly, the effectiveness of environmental protection measures is often hindered by inadequate policy implementation and enforcement. Despite the existence of environmental laws and regulations, gaps in enforcement and a lack of sufficient resources can undermine their effectiveness. Weak institutions and inadequate monitoring can also contribute to environmental degradation.

Finally, the level of public awareness and participation in environmental protection efforts plays a crucial role in mitigating conflicts. The public's overemphasis on economic development and insufficient awareness of the importance of environmental protection can exacerbate tensions between economic development and environmental protection.

## **4 THE ROLE OF RURAL LAND DEVELOPMENT AND RURAL INDUSTRIES IN RURAL ECONOMIC DEVELOPMENT AND RURAL ENVIRONMENTAL PROTECTION**

The role of land development and industry in rural economic development is complex and multifaceted. While these forces have driven economic growth, job creation, and poverty reduction in rural areas, they have also posed significant challenges to environmental protection and sustainability.

### **4.1 Historical Context and Current Trends of Rural Land Development and Township Enterprises in China**

The narrative of rural land development and the rise of township and village enterprises (TVEs) in China is intertwined with the country's broader economic reforms and modernization drive. Since the late 1970s, when the rural household responsibility system was introduced, Chinese farmers gained greater autonomy over their land and labor, spurring a wave of entrepreneurship and industrialization in rural areas. This period marked a significant shift from collective farming to a more decentralized and market-oriented economy.

Village enterprises, initially established as collective enterprises, gradually transformed into diverse forms of private, joint-stock, and cooperative enterprises. These enterprises capitalized on the country's abundant rural resources, including land, labor, and raw materials, to engage in a wide range of activities, from light manufacturing to agro-processing and services. Their emergence not only diversified the rural economy but also created job opportunities, increased incomes, and fostered regional development.

Today, the landscape of rural land development and industrialization in China is marked by both progress and challenges. On one hand, technological advancements, improved infrastructure, and policy support have facilitated the growth of more sophisticated and environmentally conscious industries. On the other hand, rapid industrialization and unchecked development have led to environmental degradation, resource depletion, and social disparities.

### **4.2 Positive Impacts of Land Development and Rural Industry on Rural Economies**

**Economic Diversification and Job Creation:** By promoting non-farm activities, land development and rural industrialization have helped diversify rural economies, reducing dependence on agriculture and mitigating the risks associated with climate change and market fluctuations. This diversification has led to the creation of numerous job opportunities, particularly for women and youth, who often face limited employment prospects in traditional agriculture.

**Income Generation and Poverty Reduction:** As rural industries thrive, they contribute significantly to household incomes and poverty reduction. Increased income levels not only improve living standards but also empower rural residents to invest in education, healthcare, and other essential services.

**Infrastructure Development:** The growth of rural industries often necessitates investments in infrastructure, such as roads, power grids, and communication networks. These investments not only facilitate industrial activities but also enhance the overall quality of life in rural areas.

**Skill Development and Human Capital Accumulation:** Rural industries, particularly those in the manufacturing and service sectors, provide platforms for skill development and professional training. This, in turn, contributes to the accumulation of human capital, which is crucial for long-term economic growth and social development.

### **4.3 Negative Impacts of Land Development and Rural Industry on Rural Ecological and Environmental Protection**

While the economic benefits of land development and rural industrialization are undeniable, their negative impacts on the environment are equally concerning.

**Land Degradation and Loss of Agricultural Land:** The conversion of agricultural land for industrial or urban uses leads to a decline in the availability of fertile land for food production. This, in turn, threatens food security and exacerbates rural poverty. Moreover, industrial activities can lead to soil degradation through contamination and erosion, further reducing the productivity of agricultural land.

**Water Pollution:** Industrial waste, including chemicals, heavy metals, and other pollutants, often ends up in rivers, lakes, and groundwater, contaminating water resources and posing health risks to rural communities. Water pollution can also disrupt ecosystems and harm aquatic life.

**Air Pollution:** Industrial activities, particularly those involving combustion processes, emit harmful gases and particulates into the atmosphere. These emissions contribute to air pollution, affecting air quality and respiratory health in rural areas.

**Biodiversity Loss:** Unplanned development and industrialization can lead to the destruction of natural habitats, threatening the survival of countless species and reducing biodiversity. Biodiversity loss undermines the resilience of ecosystems and their ability to provide essential services, such as pollination and climate regulation.

**Environmental Health Disparities:** Rural communities, particularly those located near industrial facilities, often bear the brunt of environmental pollution. These communities may lack access to clean water, safe air, and adequate healthcare, leading to increased rates of illness and mortality.

## **5 OVERVIEW OF CHINA'S LEGAL FRAMEWORK FOR ECOLOGICAL ENVIRONMENT PROTECTION AND PROMOTION OF RURAL ECONOMIC DEVELOPMENT PRIOR TO THE INTRODUCTION OF THE RURAL REVITALIZATION STRATEGY**

### **5.1 Overview of Relevant Laws and Policies for Ecological Environment Protection**

Before the implementation of the Rural Revitalization Strategy, China had established a comprehensive legal system aimed at safeguarding its ecological environment. This system encompassed a wide range of laws, regulations, and policies, not limited solely to the Environmental Protection Law. Rather, it spanned across various legal domains, each contributing to the overall goal of preserving and enhancing the country's natural resources and ecosystems.

#### **5.1.1 Key environmental protection laws**

The cornerstone of China's environmental protection efforts is the Environmental Protection Law, which sets forth basic principles, obligations, and responsibilities for environmental protection. This law emphasizes prevention-oriented principles, requiring polluters to bear the responsibility for their actions and promoting public participation in environmental protection. In addition, it outlines measures for environmental impact assessment, pollution control, and environmental monitoring, among others.

#### **5.1.2 Specialized laws for rural areas**

Recognizing the unique challenges faced by rural areas, China has also enacted specialized laws to address environmental issues specific to these regions. For instance, some local governments have also formulated rural environmental protection regulations. These rural environmental protection regulations aim to prevent and control rural pollution, promote ecological restoration, and raise the environmental awareness of rural residents. These regulations focus on issues such as agricultural waste management, rural water pollution, and soil contamination, among others.

#### **5.1.3 Cross-sectoral laws with rural environmental implications**

Several other laws, though not primarily focused on environmental protection, contain provisions that have significant implications for rural ecological environments. For example, the Forest Law protects and manages China's forests, which play a crucial role in maintaining ecological balance and biodiversity in rural areas. Similarly, the Water Law regulates the development, utilization, conservation, and management of water resources, ensuring sustainable water supplies for rural communities and agriculture.

#### **5.1.4 Policies and initiatives**

In addition to legal instruments, China has implemented numerous policies and initiatives to promote ecological environment protection in rural areas. These include national-level strategies such as the Action Plan for Prevention and Control of Soil Pollution, which aims to reduce soil contamination and improve soil quality. Furthermore, programs like

the "Beautiful China" initiative emphasize ecological restoration and green development, encouraging sustainable practices in rural economies.

## **5.2 Overview of Relevant Laws and Policies for Promoting Rural Economic Development (From the Perspective of Land Development and Industrial Advancement)**

China's pursuit of rural economic development has long been a strategic priority, with land development and industrial expansion serving as key drivers. A robust legal framework supports these efforts, ensuring that economic growth is pursued in a sustainable and equitable manner.

### **5.2.1 Land development laws and policies**

China's land laws, including the Land Administration Law and the Rural Land Contracting Law, provide the legal foundation for land development and utilization in rural areas. These laws regulate land ownership, use rights, and contracting arrangements, ensuring that land resources are allocated efficiently and equitably. Additionally, policies promoting land consolidation, reclamation, and intensive use encourage the optimization of land resources and support agricultural modernization.

### **5.2.2 Industrial development policies**

To spur rural economic growth, China has implemented a series of policies aimed at fostering industrial development in rural areas. These policies encourage the diversification of rural economies, promoting the integration of primary, secondary, and tertiary industries. For instance, the "Made in China 2025" strategy, while primarily focused on industrial upgrading nationwide, also emphasizes the development of rural industries, particularly those related to agriculture and agro-processing.

Moreover, policies aimed at supporting small and medium-sized enterprises (SMEs) in rural areas, including tax incentives, financing support, and technical assistance, have contributed to the growth of rural industries. These measures have facilitated the establishment of rural industrial parks, agro-processing clusters, and tourism-based enterprises, diversifying rural economies and creating job opportunities.

## **5.3 Issues with the Aforementioned Legal Framework**

Prior to the introduction of the Rural Revitalization Strategy, the legal framework for ecological environment protection and rural economic development, though comprehensive, faced challenges in achieving a harmonious balance between the two.

### **5.3.1 Lack of integration**

One significant issue was the lack of integration between laws and policies focused on ecological environment protection and those aimed at promoting rural economic development. Especially in rural areas, the environmental protection legal system has not yet formed a complete system, with relatively outdated content and low feasibility [1]. The former tended to prioritize environmental conservation, while the latter emphasized economic growth. This dichotomy often led to conflicts, with economic development activities sometimes compromising environmental protection efforts.

### **5.3.2 Inadequate coordination**

The lack of coordination between different government departments responsible for environmental protection and rural economic development further exacerbated the issue. Each department operated within its own mandate, with limited communication and collaboration, resulting in policy gaps and inconsistencies.

### **5.3.3 Insufficient incentives for sustainable development**

Another challenge was the insufficiency of incentives for sustainable development practices in rural areas. While policies encouraged economic growth, they often did not adequately incentivize environmentally friendly practices or penalize environmentally harmful activities. This led to a "growth-at-all-costs" mentality, with negative implications for both the environment and the long-term sustainability of rural economies.

### **5.3.4 Limited public participation and awareness**

Finally, limited public participation and awareness of environmental and economic issues in rural areas hindered the effectiveness of the legal framework. Rural residents, often lacking access to information and resources, were less engaged in decision-making processes related to environmental protection and economic development. This, in turn, limited their ability to contribute to sustainable practices and hold government agencies accountable for their actions.

In conclusion, prior to the introduction of the Rural Revitalization Strategy, China's legal framework for ecological environment protection and promotion of rural economic development, though comprehensive, faced challenges in achieving a harmonious balance between the two. The lack of integration and coordination between laws and policies, insufficient incentives for sustainable development, and limited public participation and awareness all contributed to this imbalance.

## **6 THE CRUCIAL BALANCE BETWEEN RURAL ECONOMIC DEVELOPMENT AND ECOLOGICAL PROTECTION POST THE INTRODUCTION OF THE RURAL REVITALIZATION STRATEGY: A LEGAL PERSPECTIVE**

### **6.1 The Pivotal Role of the Rule of Law in Harmonizing Rural Economic Development and Ecological Protection**

The introduction of the Rural Revitalization Strategy in China marks a significant milestone in the country's pursuit of sustainable development. At the heart of this strategy lies the delicate balance between fostering economic growth in rural areas and safeguarding their ecological integrity. The rule of law, as the cornerstone of social order and progress, plays a pivotal role in striking this balance. From the perspective of modernizing national governance, the importance of the rule of law is self-evident, and its realization requires a solid foundation of a sound legal system. In implementing the rural revitalization strategy, it is necessary to institutionalize effective policies [2]. By providing a clear framework of rights, obligations, and consequences, the legal system ensures that economic activities in rural regions are conducted in an environmentally responsible manner, while also protecting the rights of rural communities to enjoy a healthy and prosperous environment.

The legal framework surrounding rural revitalization recognizes that economic development and environmental protection are not mutually exclusive but rather complementary goals. It acknowledges that sustainable rural economies are built upon a foundation of healthy ecosystems and that the preservation of natural resources is essential for long-term prosperity. Consequently, the rule of law serves as a guiding principle, directing policies, regulations, and practices towards achieving this dual objective.

## **6.2 Integrating Ecological Protection and Rural Economic Development into the Legal Framework of Rural Revitalization**

Following the roll out of the Rural Revitalization Strategy, China has made a concerted effort to integrate the protection of the ecological environment with the promotion of rural economic development into a cohesive legal framework. This is evident in various national documents and guidance opinions, which underscore the importance of striking a harmonious balance between the two.

For instance, the Law of the People's Republic of China on the Promotion of Rural Revitalization, enacted in 2021, explicitly recognizes the need to balance economic development with environmental protection. The law outlines measures to improve agricultural productivity, foster rural industries, and support entrepreneurship while simultaneously emphasizing the conservation of agricultural genetic resources, the promotion of green technologies, and the prevention of agricultural pollution. It underscores the government's commitment to ensuring that rural development is undertaken in a manner that respects and preserves the natural environment.

Furthermore, the Chinese government has issued numerous policy documents and guidelines that reinforce this integration. For example, the "Opinions on Accelerating the Construction of Ecological Civilization" emphasizes the need to promote green and low-carbon development in rural areas, while the "The Master Plan for Major Projects of Protecting and Restoring National Important Ecosystems(2021-2035)" outlines specific targets and measures for ecological restoration and conservation in rural regions.

## **6.3 Specific Legal Provisions Promoting Rural Economic Development with Environmental Protection Requirements**

Post the introduction of the Rural Revitalization Strategy, China's legal system has been fortified with provisions that not only encourage rural economic development but also mandate environmental protection. These laws and regulations reflect a comprehensive approach to sustainable rural development.

One notable example is "Law of the People's Republic of China on the Protection of Black Soil", which imposes strict environmental standards on all economic activities, including those in rural areas. The law requires enterprises and individuals engaged in agricultural production to adopt environmentally friendly practices, such as reducing the use of harmful pesticides and fertilizers, and to comply with waste management regulations.

Additionally, the Law on the Prevention and Control of Soil Pollution specifically addresses the issue of soil contamination in rural areas, mandating measures to prevent, control, and remediate soil pollution caused by agricultural activities. This law emphasizes the importance of promoting sustainable agricultural practices and protecting agricultural land from degradation.

## **6.4 Local Governments' Implementation of Rural Ecological Protection Measures with Consideration for Economic Development Needs**

At the local level, governments have been tasked with implementing rural ecological protection measures while also taking into account the economic development needs of rural communities. This dual mandate has led to the emergence of innovative approaches that seek to reconcile the two objectives.

One such example is the implementation of eco-tourism projects in rural areas. Many localities have leveraged their unique natural resources and cultural heritage to develop eco-tourism, which not only generates economic revenue for local communities but also promotes environmental conservation. By promoting sustainable tourism practices, such as eco-lodges, hiking trails, and wildlife viewing, these projects encourage visitors to respect and appreciate the natural environment.

Another example is the promotion of green agriculture. Local governments have incentivized farmers to adopt environmentally friendly farming practices, such as organic farming, integrated pest management, and precision agriculture. These practices not only reduce the use of harmful chemicals but also improve soil health and crop yields, leading to increased economic returns for farmers.

Moreover, local governments have also implemented programs aimed at improving rural infrastructure while minimizing environmental impacts. For instance, they have invested in renewable energy sources, such as solar and wind power, to meet the energy needs of rural communities while reducing greenhouse gas emissions. They have also prioritized the construction of eco-friendly public facilities, such as waste treatment plants and green spaces, to enhance the quality of life for rural residents.

In conclusion, the introduction of the Rural Revitalization Strategy in China has underscored the importance of striking a balance between rural economic development and ecological protection. The rule of law has played a crucial role in this endeavor, providing a clear framework for policies, regulations, and practices that promote sustainable rural development. By integrating ecological protection into the legal framework of rural revitalization, China has demonstrated its commitment to ensuring that rural economies thrive without compromising the health and integrity of the natural environment.

## **7 SUGGESTIONS FOR FURTHER IMPROVING CHINA'S RURAL REVITALIZATION LEGAL SYSTEM**

### **7.1 Further Improvement of the Legal and Regulatory Framework**

To address the unique challenges posed by land development and industrial expansion in rural areas, it is crucial to formulate or amend relevant environmental protection clauses. These clauses should specifically address issues such as soil contamination, water resource management, and air pollution, ensuring that economic development does not come at the cost of ecological degradation. The legislation should also mandate sustainable practices and set clear guidelines for mitigating negative environmental impacts.

**Strengthening Environmental Impact Assessment and Approval Systems:** The existing environmental impact assessment (EIA) and approval processes must be strengthened to ensure rigorous scrutiny of all proposed rural development projects. This includes implementing more stringent criteria for evaluating potential environmental risks, increasing transparency in the approval process, and ensuring timely and effective public consultation. The system should also facilitate prompt corrective measures in case of non-compliance or unforeseen environmental impacts.

### **7.2 Enhancing Environmental Law Enforcement and Supervision**

To enhance the efficiency and effectiveness of environmental law enforcement, a robust inter-departmental collaboration mechanism should be established. This involves coordinating efforts among agencies responsible for agriculture, environment, land use planning, and industry to ensure seamless information sharing, joint inspections, and coordinated enforcement actions. Such collaboration can help identify and address environmental violations promptly.

We should seriously deal with enterprises that violate the red line of environmental protection and governance, reduce the environmental pollution caused by enterprises, restrict the behavior of enterprises themselves, thereby promoting the rural process of rural revitalization, improve the utilization rate of environmental protection resources, and stimulate the ecological vitality of the countryside [3]. To create a deterrent effect, penalties for environmental violations must be significantly increased and strictly enforced. This includes fines, criminal prosecutions where appropriate, and the imposition of corrective measures. Publicizing successful prosecutions and the consequences of non-compliance can further amplify the deterrent effect, fostering a culture of compliance among businesses and individuals involved in rural development.

### **7.3 Promoting Public Participation and Oversight**

Raising public awareness of the importance of environmental protection is the key to reducing rural environmental pollution [4]. To enhance public engagement in rural environmental protection, diverse participation channels should be created or expanded. This can include organizing public hearings, workshops, and community consultations to gather feedback on proposed development projects. Additionally, establishing online platforms where citizens can report environmental issues and track progress of remediation efforts can further democratize environmental governance.

**Establishing Environmental Information Disclosure Systems:** Ensuring public access to environmental information is fundamental to fostering transparency and accountability. An environmental information disclosure system should be established, mandating the timely release of key environmental data, including pollution levels, project EIA reports, and enforcement actions. This will empower citizens to make informed decisions, exercise their right to know, and actively participate in monitoring and overseeing environmental management efforts.

### **7.4 Innovating Ecological Compensation and Incentive Mechanisms**

**Exploring Ecological Compensation Mechanisms:** To balance economic development with ecological conservation, innovative ecological compensation mechanisms should be explored. Additionally, establishing market-based mechanisms like carbon trading or ecosystem service payments can incentivize environmental stewardship and provide financial incentives for sustainable development [5].

**Encouraging Green Technology Innovation and Industrial Transformation:** To achieve sustainable rural development, it is imperative to encourage green technology innovation and promote industrial transformation. Policies should support research and development of environmentally friendly technologies, provide incentives for businesses to adopt clean

production methods, and facilitate the transition to low-carbon, circular economies. To promote green rural development, green agricultural development initiatives should be carried out to reduce the input of agricultural production, ensure clean production, recycle waste, and establish an ecological industrial model [6]. By fostering a green economy, rural areas can not only protect their natural resources but also harness the opportunities presented by the global transition to sustainable development.

## **8 SIGNIFICANCE OF ESTABLISHING A LEGAL FRAMEWORK FOR RURAL REVITALIZATION IN CHINA**

The establishment of a comprehensive legal system for rural revitalization in China holds profound significance, not only for the nation's rural areas but also for the global community. This framework addresses critical issues related to economic development, environmental protection, and social welfare, thereby fostering sustainable and inclusive growth.

### **8.1 Facilitating Coordinated Development of China's Rural Economy and Environment**

Ancient Chinese traditional culture believed that human beings and the natural environment share a relationship of "when one falls, the other falls; when one prospers, the other prospers", and opposed the overexploitation of the environment [7]. The legal framework for rural revitalization in China plays a pivotal role in ensuring the harmonious coexistence of economic growth and environmental preservation in rural regions. By outlining clear guidelines and regulations, it encourages sustainable agricultural practices that minimize the use of harmful chemicals, promote eco-friendly farming techniques, and conserve natural resources. This not only enhances agricultural productivity and rural economies but also safeguards the quality of air, water, and soil, thereby preserving the ecological balance essential for long-term prosperity. Furthermore, it fosters a culture of environmental responsibility among rural communities, encouraging them to actively participate in conservation efforts and adopt green lifestyles.

### **8.2 Contributing to Pollution Reduction and Global Carbon Emission Mitigation**

The rural revitalization legal system contributes significantly to reducing pollution and mitigating global carbon emissions. By promoting renewable energy sources, energy-efficient technologies, and circular economy models in rural areas, it helps decrease reliance on fossil fuels and minimize greenhouse gas emissions. Additionally, regulations aimed at preventing industrial pollution from migrating to rural areas and promoting waste management and recycling practices further contribute to environmental protection. As China, being a major emitter, takes these steps, it sets an example for other nations, demonstrating that economic growth and environmental stewardship can go hand in hand. This, in turn, accelerates global efforts towards achieving climate change targets and fostering a greener planet.

### **8.3 Providing Lessons for Other Developing Countries Worldwide**

Firstly, China's rural revitalization legal framework offers valuable insights to other developing countries seeking to boost their rural economies. It emphasizes the importance of diversifying rural economies beyond traditional agriculture, promoting value-added agriculture, and fostering rural entrepreneurship. By investing in infrastructure, education, and healthcare, China has created an enabling environment for rural businesses to thrive, thereby increasing income opportunities for farmers and reducing rural-urban disparities. Other nations can learn from these strategies to stimulate their own rural economies and reduce poverty.

Secondly, the legal framework also underscores the need to protect and enhance rural human settlements, ensuring that rural residents enjoy safe, healthy, and livable environments. This includes promoting sustainable land use planning, improving access to clean water and sanitation, and preserving cultural heritage and traditional lifestyles. By implementing these measures, China has demonstrated that rural revitalization can be achieved without compromising the quality of life for rural residents. Other developing countries can adopt similar policies to safeguard their rural landscapes and communities.

Lastly, China's rural revitalization efforts are centered on improving the living standards of farmers. The legal framework supports policies that increase farmers' access to education, healthcare, and social security, thereby enhancing their overall well-being. It also promotes fair trade practices, ensuring that farmers receive a fair share of the value chain, and encourages the adoption of modern farming techniques to increase productivity and income. These initiatives serve as a model for other developing countries, illustrating how comprehensive policies can empower rural communities and lift millions out of poverty.

## **9 CONCLUSION**

The state of human civilization is closely related to that of ecological civilization, and we must improve the legal system for ecological and environmental protection from the perspective of pursuing harmonious coexistence between human and nature [8]. The establishment of a robust legal framework for rural revitalization in China is of paramount importance, not only for the nation's own development but also for the global community. It fosters sustainable



economic growth and environmental protection, contributes to global climate action, and provides valuable lessons for other developing countries striving to achieve rural prosperity.

### **COMPETING INTERESTS**

The author has no relevant financial or non-financial interests to disclose.

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# DESIGN AND PRACTICE OF TPRS INTERNATIONAL CHINESE TEACHING MODEL FROM THE PERSPECTIVE OF THE CULTIVATION OF HIGHER-ORDER THINKING SKILLS

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**Abstract:** TPRS (Teaching Proficiency through Reading and Storytelling) is a story-oriented language teaching method, which emphasizes language learning in natural and interesting contexts and promotes students' independent learning and in-depth thinking. Since its introduction, the TPRS method has been recommended by foreign language teachers of different languages, more and more foreign language teachers have verified the remarkable effectiveness of TPRS in their teaching practice, and the relevant research results have also been enriched and developed. However, in the teaching of Chinese as a second language, there is still a relative lack of application and research on TPRS, especially for the cultivation of higher-order thinking skills. This paper attempts to supplement and improve the TPRS pedagogy through a series of teaching strategies and activities, such as real-life context motivation, group cooperation, continuation task, etc., in order to effectively cultivate and develop higher-order thinking skills of international students.

**Keywords:** Higher-order thinking; TPRS; International Chinese teaching; Cooperative learning; Continuation task

## 1 INTRODUCTION

Higher-order thinking is a hot topic in current international education research. Cultivating and developing students' higher-order thinking has become an inevitable requirement for cultivating innovative talents in the new era and a great challenge for higher education as well. In international Chinese language teaching, cultivating international students' higher-order thinking ability while realizing the goal of Chinese language teaching is an important issue which the innovation of international Chinese language class teaching faces, and it is also the key breakthrough to implement the core qualities of international Chinese language discipline and to cultivate innovative talents.

The excellent effectiveness of TPRS in second language teaching class has been widely verified, but there are many problems in the class teaching practice of Chinese as a second language, such as focusing on the teaching of language knowledge and skills, and the lack of teaching measures to cultivate students' higher-order thinking skills, such as analyzation, evaluation, and creativeness. This is the core issue explored in this paper.

## 2 THE DESIGN OF TPRS TEACHING ACTIVITIES FOR THE CULTIVATION OF HIGHER-ORDER THINKING SKILLS

The TPRS teaching method consists of three basic parts: establishing meanings of vocabulary, story inquiry, and reading and discussion. In the section of establishing meanings of vocabulary, the meanings of the new language are shown directly to students and placed in an appropriate place for them to view them at any time; In the story inquiry section, the teacher sets up a story outline in advance and guides students to construct personalized stories by using the vocabulary they have learned and by asking questions and using pictures to prompt them; After the story construction process, reading and discussion section follows. The teacher will organize the complete story into a text, present it to students in the form of Pinyin and Chinese characters, and organize students to read aloud for review, so as to complete the connection of sound, meaning, and writings. The teacher then assigns reading materials for translation practice and asks questions about the content of the story.

Based on completing the above TPRS lower-order thinking stage of memorization and understanding, this paper designs a series of practical application activities, and transfer and innovation activities to help students realize the natural "climb" from lower-order thinking to higher-order thinking.

### 2.1 Real Situation Motivation

#### 2.1.1 Function of real situation motivation

The so-called "real", in simple terms, means that the design of the project is linked to the real world or personal experience. The "real" is the reason for learning, not for the exam, and it makes students know why the concept or idea is important and why it took so long to explore the topic or issue. When students know exactly how what they do affects them and the world around them, they will have a stronger internal motivation to keep learning and exploring [1].

As a mode of thinking in which multiple cognitive components act synergistically, the development of higher-order thinking relies on a learning situation close to real-life experiences to activate the cognitive components therein [2]. Teachers create challenging learning tasks in real-life contexts, and students acquire information and knowledge in a

targeted manner while solving problems or completing projects [3]. Effective learning and teaching models should be based on questions with no definite answers in authentic situations, giving students the opportunity to explore and construct, facilitating the identification of connections between a prior knowledge and new information, and helping students integrate old and new knowledge to construct a cognitive model that is coherent with others and dynamically updated [4].

Drawing on the motivation session of Production-oriented Approach, an authentic language communication situation is set up before the first session of TPRS, to establish meanings of vocabulary, so that learners can try to complete some seemingly simple and ordinary, but actually challenging communication tasks, and then the teacher explains the teaching objectives and output tasks. The purpose of this motivation is to make learners feel the sense of urgency and hunger due to the lack of their own language proficiency, so that they can be more active in input learning for accomplishing the output tasks.

### 2.1.2 Teaching design of real situation motivation

[Case 1] Take the textbook New Era Spoken Chinese Series, Elementary Level·II, Lesson 5 “Payment by cell phone is OK” for example, the theme of this unit is payment methods. The motivation is divided into four steps, as shown in Table 1:

**Table 1** Lesson Plan Design

Number	Step	Content								
1	Opening: the teacher asks questions to introduce the topic of the unit	<ol style="list-style-type: none"> <li>1. Have you ever used a cell phone to make a payment? When did you use it?</li> <li>2. What do you think are the advantages of cell phone payment?</li> </ol>								
2	Show the video about cell phone payment, present the communication scene and ask students to think about two questions	<ol style="list-style-type: none"> <li>1. When did she use cell phone payment?</li> <li>2. What advantages does she think there are in paying by cell phone?</li> </ol>								
3	Students try to implement the communicative activities and tasks	<p>A. Group activities In groups of 3-4, introduce to each other: cash, bank card, and cell phone, which method of payment do you often use? Which one do you not often use? Why?</p> <p>1. Preparation: fill in the blanks with the key words.</p> <table border="1"> <thead> <tr> <th></th> <th>Reason</th> </tr> </thead> <tbody> <tr> <td>I usually use _____ to make payments.</td> <td></td> </tr> <tr> <td>I usually don't use _____ to make payments.</td> <td></td> </tr> <tr> <td>I don't use _____ to make payments.</td> <td></td> </tr> </tbody> </table> <p>2. Have a talk: give an introduction to each other, according to what you have written.</p> <p>B. Ask a group of students to give an introduction to the class.</p>		Reason	I usually use _____ to make payments.		I usually don't use _____ to make payments.		I don't use _____ to make payments.	
	Reason									
I usually use _____ to make payments.										
I usually don't use _____ to make payments.										
I don't use _____ to make payments.										
4	Teacher explains the teaching objectives and output tasks	<ol style="list-style-type: none"> <li>1. Learn expressions related to payment.</li> <li>2. Introduce clearly how to make payments with a cell phone.</li> <li>3. Discuss and compare several common payment methods.</li> </ol>								

### 2.1.3 Design note of case 1

The motivation session covers three characteristics: communicative authenticity, cognitive challenge and appropriateness of output objectives [5]. The reasons are as follows:

(1) Communicative authenticity: the communicative scenarios set in the unit are students shopping, dining, traveling, etc. in consumer places, thus they can feel the authenticity of the existence of these situations;

(2) Cognitive challenging: to complete the two communicative activities in the group and class, students not only need to have background knowledge reserves related to the topic of payment, but also need to describe and explain the payment preferences with appropriate forms of linguistic expressions, which is undoubtedly a challenge to students' knowledge accumulation and language proficiency. At the same time, the three cognitive processes of differentiation, organization and attribution in students' analytical thinking skills are expanded;

(3) Appropriateness of output objectives: the three communicative objectives of this motivation session belong to description with identification, explanation and evaluation respectively. The first two subgoals are less difficult and serve the third objective, the unit objective. The third objective requires students to use critical thinking to give evaluations and to judge which way of payment is the most effective. This requires a certain level of difficulty in terms of students' evaluation skills. Thus, the goal setting follows the principle of gradual progression and reflects the appropriateness of the output objectives.

## 2.2 Cooperative Learning

The development of higher-order thinking relies on learning contexts that are close to real social interaction experiences as well as cooperative, interactive, and constructive learning modes to promote the synergistic development of multiple cognitive components [6]. The student-centered cooperative learning model promotes the development of higher-order thinking skills such as deeper understanding, language expression, argumentative reasoning, problem solving, and knowledge transfer to varying degrees [7]. Cooperative learning, as a learning mode that can effectively promote the development of students' higher-order thinking, needs to rely on a good instructional design so that it can be organically integrated into the TPRS teaching class.

### 2.2.1 Student questioning

The American psychologist Brubaker said, "The most exquisite art of teaching follows the highest principle of letting students ask questions." Teachers in the TPRS teaching to encourage students to ask questions, improve students' ability to ask questions, will stimulate students' thinking initiative, promote their thinking from multiple perspectives, so that the TPRS class is more "open and dynamic".

#### 2.2.1.1 Students questioning in the story inquiry session

Circular questioning is the core of TPRS story inquiry. The teacher asks multiple questions about each part of the target sentence (yes-or-no questions, positive and negative questions, alternative questions, and special questions), and then students answer them, and students' multiple answers will inadvertently repeat the target sentence many times. However, the multiple applications of this strategy tend to make students feel bored and tired, and then they may ignore different details of the questions and answer the target sentences mechanically [8]. Therefore, after the teacher finishes the circular questioning of the target sentence, he/she can ask the students to do the cycle again.

[Case 2]

Teaching session: circular questioning of the target sentence "Wang Mei wanted to pay by cell phone".

The classroom screen displays the sentence "Wang Mei wanted to pay by cell phone" and the words "ma", "who", "what", "or" in Chinese characters, Pinyin, and English translation. The students called Lin Zhi, Wang Mei and Meng Ke participate in asking questions. The dialogue between the teacher and students is as follows:

Teacher: Did Wang Mei want to pay by cell phone?

Students: Yes! Wang Mei wanted to pay by cell phone.

Lin Zhi: With what did Wang Mei want to pay?

Students: Wang Mei wanted to pay with her cell phone.

Wang Mei: Who wanted to pay by cell phone?

Students: Wang Mei wanted to pay with her cell phone.

Meng Ke: Did Wang Mei want to pay by cell phone or by cash?

Students: Wang Mei wanted to pay with her cell phone.

[Design note] In the above teaching session, it is no longer just the teacher who asks questions, but the students also participate in the questioning. In order to enable students to complete the questioning cycle smoothly, the teacher provides the Super 7 and Freebies to scaffold students' language output. This activity aims to cultivate students' freedom to ask different questions according to their individual language ability by using the prompted interrogative words in the form of cooperative teacher-student and student-student questioning and answering, which enhances the fun, and at the same time accomplishes the memorization and understanding of the lower-order thinking stage and lays the foundation for the subsequent higher-order questioning.

#### 2.2.1.2 Students questioning in the reading and discussion session

In the third session of reading and discussion in TPRS, after students complete the exercises of reading aloud, translation, and reading comprehension of the story text, they enter the following part: (1) turn-taking questioning and answering (2) higher-order questioning.

##### 2.2.1.2.1 Turn-taking questioning and answering

[Case 3] This case is adapted from the textbook *New Era Spoken Chinese Series, Elementary Level · II, Lesson 5 "Payment by cell phone is OK"*.

Teaching session: questioning and answering in rotation according to the story "Wang Mei and I went to the supermarket to buy fruits".

The teacher and students take turns quizzing on the story “Wang Mei and I went to the supermarket to buy fruits”, while the classroom screen displays the story in Chinese and Pinyin. The text of the story is as follows:

Today Wang Mei and I went to the supermarket to buy fruits, and she paid with her cell phone, which was very convenient. I asked her to teach me. She told me that I could pay with WeChat and taught me to tie my bank card to WeChat Pay, so I can pay with my cell phone from now on. Although I can try “Sweep” and “Receive Payment”, I am still used to using cash. Only when I use cash can I remember how much I spent. Also, I don't think it's safe to make payments with my cell phone, in case someone else uses my cell phone!

The dialogue between the teacher and students is as follows:

Teacher: Did Wang Mei pay in cash?

Lin Zhi: Wang Mei didn't pay in cash. What did Wang Mei use to pay?

Wang Mei: Wang Mei paid with her cell phone. What did you pay with?

Meng Ke: I paid with cash. What did Wang Mei teach me to do with WeChat?

Wang Mei: Make a payment. Why do you think it's not safe to pay with your cell phone?

Lin Zhi: In case someone else uses my cell phone! Why did Wang Mei pay with her cell phone?

Meng Ke: Because it was convenient.

[Design note] When students take turns to quiz on the story content, they first take reading input and then take the transferable output of answers and questions. The whole class participates in the class interaction in an orderly manner to further consolidate their understanding of the story. This activity is the same as the previous students circular questioning part in that students choose the questions with which they are most comfortable, and the questions posed are relatively single and simple, belonging to the lower-order category.

#### 2.2.1.2.2 Higher-order questions

When encouraging and guiding students to ask higher-order questions, teachers should form heterogeneous groups according to students' ability level, learning needs and personality traits, and carry out hierarchical teaching.

First, for students who are excellent in Chinese language learning, teachers can encourage them to think beyond the text of the story and inspire them to ask comparative and extended questions. Take the above story as an example of the text as follows:

(1) Which method of payment do you think Wang Mei is used to? How did she pay with her cell phone? Such questioning can train students' reasoning and judgment skills;

(2) Do you think it is convenient to pay by cell phone? Why? Do you think the author's concerns are necessary? Why? Through these questions, students are guided to apply their newly learned knowledge and improve their analyzing and evaluating skills;

(3) If you were Wang Mei, what would you do to dispel the author's concerns? How could the story be rewritten if the author was used to paying by credit card? These questions require students to synthesize their analytical, evaluative, and creative thinking skills.

Through independent questioning, students think and progress in stages. Their thinking skills are mobilized and activated, their analytical, critical, and creative thinking skills are further enhanced, and higher-order thinking skills are developed.

Then, these excellent students are assigned to different groups for group discussion, and they drive their group members to actively ask higher-order questions and answer them after individual thinking.

Asking and answering questions in groups allows students with low cognitive levels to have the opportunity to participate in class questioning and prevents students with high cognitive levels from blurting out answers. This ensures that each student has equal opportunities to participate in class interaction, and promotes the development of each student's self-cognitive level as well, and at the same time promotes the realization of their reading goals in common, and creates their own reading “sharing” class, exploring the mysteries of the text and discovering the joy of reading in cooperation.

#### 2.2.2 Role play

In the reading session, students can be asked to play the roles in the story and analyze the psychological activities of the characters in the story in groups, in order to develop the quality of their creative thinking [9]. Then they share their own group's performance in class and receive evaluation and feedback from other groups. This trains students' analytical and evaluative ability, and develop their critical thinking as well.

#### 2.2.3 Students' video making of the story

The teacher transforms the story into a video. After watching the teacher's video example, students work in groups to create personalized story videos after class. In next class, the teacher shows the students' videos and the students compare, quiz, and evaluate their videos.

As the video comprehensively presents the picture, voice, text and other elements, the presentation is more vivid, graphic and detailed, and the teacher and students can dig into the discussion of richer content in the process of reading and discussing session [10]. This is conducive to stimulating students' learning initiative, activating students' comprehensive use of thinking ability for analysis, assessment and creativeness.

Cooperative learning stimulates students' awareness of autonomous participation, realizes the student transformation of the participation form from passive to active, and fully develops students' higher-order thinking skills.

### 2.3 Continuation Task

This paper recommends the reading-writing integrated continuation task as a complement and refinement to the writing session. This pedagogy advocates maximizing the synergy between output and comprehension in conjunction with external input [11]. The continuation task activates almost all the positive factors that contribute to language learning, including the most important, learners' initiative [12].

The continuation task is placed after the reading discussion. The student makes up a story based on the one constructed in the unit in various ways: change the ending of the story, add new characters, or guess the development of the story, continuing the author's intention of writing. Meanwhile, the vocabulary list and the story built in class can be used as auxiliary language materials to be consulted when needed, with the aim of allowing students to imitate the language style and the target language of the unit, to organize as much as possible a richer language based on the topic of the unit, and to cultivate analytical, creative and critical thinking skills.

### 3 CONCLUSIONS

The exploration of TPRS teaching mode from the perspective of the higher-order thinking is a deepening development based on the existing TPRS mode. Through profound, effective, diversified and appropriate teaching strategies and activities, combined with the cognitive rules and psychological characteristics of students, students' higher-order thinking abilities such as analyzation, evaluation and creativeness are stimulated and developed, so that the core literacy of the international Chinese language discipline can really be realized in the TPRS teaching.

### COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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# UNIFORM RU NANOPARTICLES WITH MGO SUPPORTED ON BETA ZEOLITE FOR EFFICIENT HYDROGEN GENERATION FROM AMMONIA BORANE HYDROLYSIS

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**Abstract:** Hydrogen energy has garnered widespread attention as a key component of the future energy landscape. However, the safe storage and transportation of hydrogen remain significant challenges to its widespread adoption. Solid chemical hydrogen storage materials, such as ammonia borane, offer a promising solution by enabling safe storage under conventional conditions while allowing rapid hydrogen release in the presence of noble metal catalysts. Nevertheless, the high cost of these noble metal catalysts limits their practical application. In this study, we developed a highly dispersed Ru-based nanoparticle catalyst (< 2 nm) supported on commercial zeolites using a simple ion exchange method. This approach significantly enhances catalytic performance and increases Ru utilization, effectively reducing catalyst costs. Additionally, incorporating magnesium oxide further enhances catalytic activity, providing a feasible strategy for designing efficient hydrogen production catalysts. This work presents a cost-effective approach to advancing hydrogen energy applications.

**Keywords:** Metal nanoparticle; Zeolite; Hydrogen energy; Hydrogen generation; Hydrolysis reaction

## 1 INTRODUCTION

Hydrogen energy is increasingly recognized as a cornerstone of future clean energy systems due to its high energy density and environmentally friendly nature.[1-6] However, a significant challenge remains in the safe and efficient storage and transportation of hydrogen. Conventional methods, such as high-pressure gas storage and cryogenic systems, pose safety concerns and logistical difficulties.[7-11] Liquid chemical hydrogen storage materials, particularly ammonia borane (AB), offer a safer and more practical solution by allowing hydrogen to be stored under ambient conditions and released on-demand through catalytic processes.[12-16] While noble metal catalysts, especially Ru, are highly effective in facilitating hydrogen release from AB, their high cost and scarcity limit their widespread application.[17-20] Therefore, there is a strong demand for more efficient and cost-effective catalytic systems that reduce the reliance on noble metals without sacrificing performance.

Zeolites, as a class of highly porous materials, have gained significant attention in recent years for their ability to enhance catalytic performance through confinement effects.[21,22] The well-ordered microporous structure of zeolites, consisting of a three-dimensional network of channels and cavities, allows for the encapsulation and dispersion of metal nanoparticles, preventing their agglomeration and enhancing stability. Various studies have demonstrated the effectiveness of zeolites in stabilizing noble metal catalysts while promoting their activity.[23,24] For instance, research has shown that zeolite-supported platinum and palladium nanoparticles exhibit superior catalytic activity and stability due to the spatial constraints provided by the zeolite framework. These confinement effects ensure that the nanoparticles remain highly dispersed, increasing the available surface area for catalytic reactions and protecting them from sintering under harsh conditions. This unique property of zeolites makes them ideal candidates for supporting noble metal catalysts in hydrogen storage and production applications.[25] Building on this body of work, our study explores the potential of zeolites as a support material for highly dispersed Ru nanoparticles in hydrogen release from AB.

In this study, we developed a novel catalytic system by confining Ru nanoparticles, with a size of less than 2 nm, within the pores of commercial zeolites using a simple ion exchange method. The zeolite support effectively controls the growth and distribution of the Ru nanoparticles, ensuring a high degree of dispersion and preventing particle aggregation. This confinement effect significantly enhances the catalytic activity of Ru, as the increased surface area of the dispersed nanoparticles leads to more efficient hydrogen release from AB. Moreover, the porous structure of the zeolite provides a protective environment, improving the stability and durability of the catalyst under reaction conditions. To further improve the system's efficiency, we incorporated MgO nanoparticles as a co-catalyst. The combination of Ru confinement within the zeolite matrix and the promotional effect of MgO resulted in a highly efficient and cost-effective catalytic system for hydrogen production. This work demonstrates the potential of zeolite-based confinement strategies for optimizing noble metal catalysts and offers a promising pathway for developing advanced catalysts for hydrogen energy applications.

## 2 METHODS

### 2.1 Preparation of Catalysts

The uniform Ru nanoparticles supported on Beta zeolite were prepared by ion exchange method. Typically, 1 g of Beta zeolite ( $\text{Si}/\text{Al}_2\text{O}_3 = 25$ ) was dissolved in 10 g of water. After adding a specific volume of  $\text{RuCl}_3$  solution, the mixture was stirred for 2 hours. The solid formed was then washed twice with water to remove any remaining impurities. The final step involved reducing the catalyst powder under pure hydrogen at 573 K for 2 hours, resulting in the synthesis of the Ru/Beta-IE catalyst.

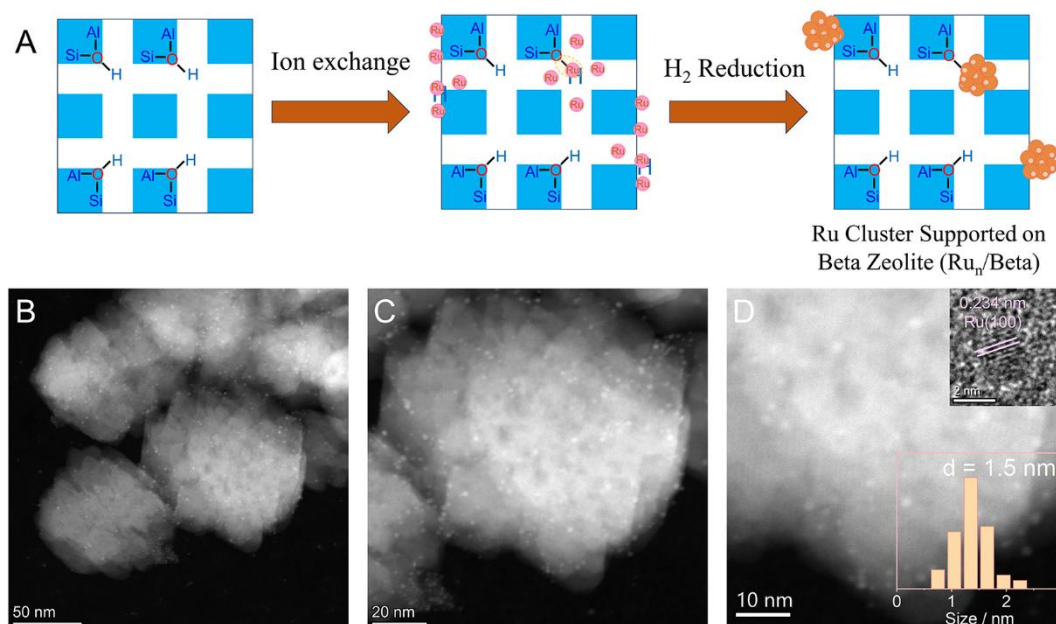
For the Ru-MgO/Beta catalyst, the Beta zeolite was impregnated with  $\text{Mg}(\text{NO}_3)_2$  solution and calcined at 773 K before fabrication of Ru nanoparticle.

## 2.2 Catalytic Test

A two-necked 25 mL round-bottom flask was prepared by mixing an appropriate amount of catalyst with 0.5 mL of water. The flask was then placed in a water bath and stirred magnetically at 600 rpm, maintaining the temperature at 298 K under ambient conditions. To initiate the reaction, 0.5 mL of a 2.0 M aqueous ammonia borane (AB) solution was injected into the flask using a syringe, ensuring that the molar ratio of metal to AB remained constant. The volume of gas generated during the reaction was measured using a gas burette, while the mass changes were recorded with an electronic balance.

## 3 RESULTS

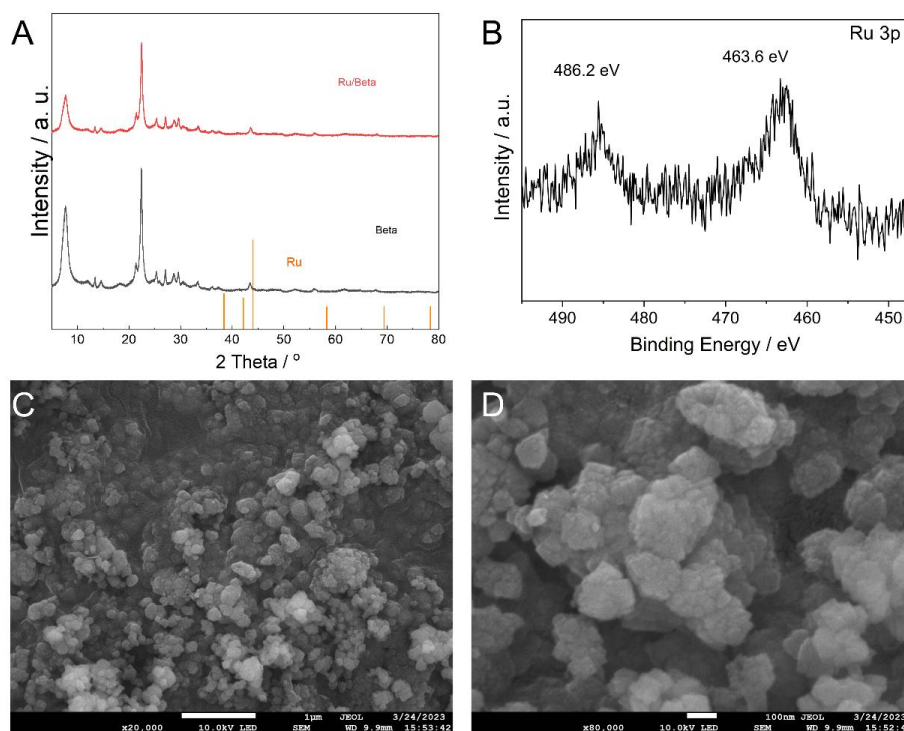
The preparation of the Ru/Beta-IE catalyst is visually outlined in Figure 1A. This schematic illustrates the ion exchange method used for synthesizing the catalyst. Figures 1B-D present scanning transmission electron microscopy (STEM) and high-resolution transmission electron microscopy (HR-TEM) images of the catalyst. These images reveal that the Ru nanoparticles are uniformly dispersed on the Beta zeolite, with a particle size below 2 nm. The STEM images confirm the high dispersion and uniform size distribution of the Ru nanoparticles confined within zeolite channels, indicating successful synthesis with no aggregation, which is critical for maximizing the catalytic surface area and ensuring stability during the reaction. The HR-TEM images further demonstrates Ru nanoparticles with lattice spacing of 0.234 nm, which is attributed to crystal face (100) of Ru metal.



**Figure 1** A Scheme for the Preparation of Ru/Beta-IE Catalyst by Ion Exchange Method. B-D STEM Images and High-resolution TEM Image for the Ru/Beta-IE Catalyst

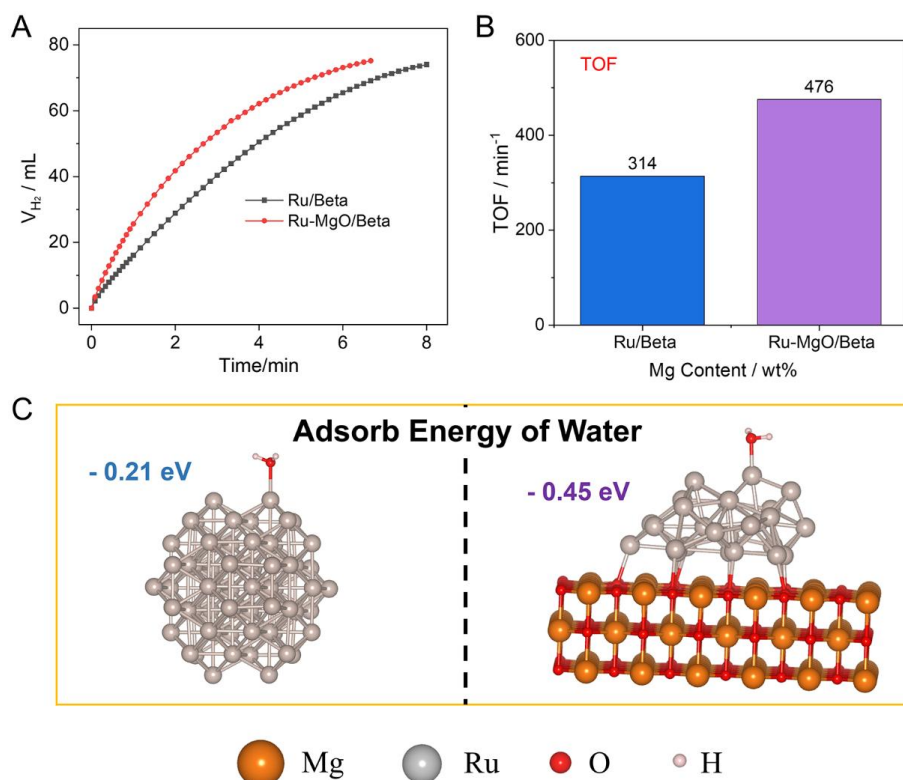
In Figure 2A, X-ray diffraction (XRD) patterns of both the Ru/Beta-IE catalyst and the Beta zeolite are presented. The absence of distinct Ru peaks in the Ru/Beta-IE sample suggests that the Ru nanoparticles are highly dispersed and below the detection limit of the XRD, confirming their small size and high distribution. Figure 2B presents the Ru 3p X-ray photoelectron spectroscopy (XPS) spectra, highlighting the chemical state of Ru in the catalyst. The spectra indicate that Ru is predominantly present in a metallic state, which is essential for catalytic activity. Figures 2C-D provide further SEM images, demonstrating the high stability of the zeolite support, consistent with the findings in Figure 1.





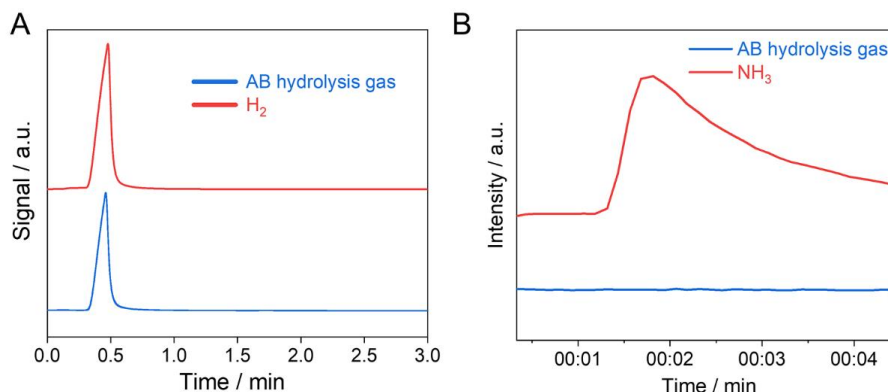
**Figure 2** A XRD Patterns of Ru/Beta-IE and Beta Samples. B Ru 3p XPS Spectra for the Ru/Beta-IE Catalyst. C-D SEM Images for the Ru/Beta-IE Catalyst

In Figures 3A-B, the catalytic performance of the Ru/Beta-IE catalyst is evaluated through hydrogen generation experiments. The graphs display the volume of hydrogen released over time during the hydrolysis of ammonia borane (AB). The Ru/Beta-IE catalyst exhibits excellent activity, with rapid hydrogen release and high overall yield. This enhanced performance is attributed to the high dispersion of Ru nanoparticles and the confinement effect provided by the Beta zeolite support. The incorporation of MgO further enhances the catalytic performance, as indicated by the higher hydrogen generation rates compared to other catalysts, increasing the TOF value from  $314 \text{ min}^{-1}$  to  $476 \text{ min}^{-1}$ . This could be attributed to the increasing adsorb energy of water from 0.21 to 0.45 eV, as shown in Figure 3C, validating the effectiveness of the Ru/Beta-IE system in hydrogen production applications.



**Figure 3** A-B The Catalytic Performance of the Ru/Beta-IE and Ru-MgO/Beta C-D Adsorb Energy of Water for the Ru/Beta-IE and Ru-MgO/Beta Catalyst

Figure 4 presents the analysis of the gas products generated during the catalytic hydrolysis of ammonia borane (AB) using the Ru/Beta-IE catalyst. The gas composition was analyzed using gas chromatography with a thermal conductivity detector (GC-TCD) and mass spectrometry (MS). The results confirm that the gas produced is pure hydrogen, with no detectable traces of ammonia or other by-products. This is crucial for hydrogen energy applications, as the absence of ammonia ensures the purity of the hydrogen fuel and prevents potential contamination issues in downstream processes. The high purity of the hydrogen produced further highlights the efficiency and selectivity of the Ru/Beta-IE catalyst system, making it highly suitable for practical hydrogen production applications.



**Figure 4** **A** The GC-TCD spectra of Gas Product in Ammonia Borane Hydrolysis. **B** The Mass Spectrometry of Gas Product in Ammonia Borane Hydrolysis

#### 4 CONCLUSION

This study successfully demonstrates the potential of zeolites as effective support material for noble metal catalysts, specifically for hydrogen release from ammonia borane. By confining ruthenium nanoparticles within Beta zeolites, we achieved highly dispersed Ru particles, smaller than 2 nm, which significantly improved the catalytic performance. The zeolite's confinement effect not only enhanced the catalyst's efficiency by increasing the active surface area but also stabilized the Ru nanoparticles, preventing agglomeration and extending their durability. Additionally, the incorporation of MgO nanoparticles as a co-catalyst further boosted the system's efficiency, making it a cost-effective solution by reducing the reliance on precious metals. This work highlights the importance of utilizing porous materials like zeolites for catalyst development and opens up new possibilities for designing advanced, scalable catalytic systems for hydrogen storage and production.

#### COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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