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Research on the Integration Mode of Teaching and Competition Based on 3D Digital Innovation Design Competition

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Abstract: The deep integration of competitions and teaching is beneficial to the innovative capabilities of students and the teaching reform, so it is essential to build a competition-teaching integration model to explore the influences of the competition on the promotion of curriculum teaching, practical teaching, and faculty development. Firstly, based on the data from the National 3D Digital Innovation Design Competition (3D Competition), the participation data is analyzed by the current performance of students in 3D digital innovation design in terms of the quantity, quality, innovation points, and technological application of their works. Then, taking into account the curriculum system integration, teaching integration and faculty integration, a specific model for the integration of competitions and teaching is proposed to organically incorporate competition content, cases, and outcomes into the entire teaching process. Through the analysis of the outcomes in the advance of the innovative abilities of students, the teaching models, and the university-industry collaboration in Nanyang Institute of Technology, the practical measures and achievements in integrating the 3D Competition with teaching are illustrated in detail. This study provides theoretical support and practical references for universities to improve teaching and learning through competitions, and propel innovative talent cultivation and teaching reform.

Keywords: 3D Competition; Innovative design; Competition and teaching integration; Data analysis

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1. Introduction

With the rapid development of 3D digital technology and its deep penetration into fields such as industrial design, intelligent manufacturing, and virtual simulation, higher education is facing the transformation challenge from knowledge imparting to innovative ability cultivation. It is clearly stated that deep education and teaching reform can strengthen the practical education link in China Education Modernization 2035 [1]. As an important bridge connecting theory and practice, subject competitions are becoming increasingly valuable. The National 3D Digital Innovation Design Competition (3D Competition), as the largest 3D digital innovation practice platform in China, has attracted more than 600 universities and 300,000 students to participate in the past five years [2]. The

data of 3D Competition contains valuable clues about the innovative ability characteristics of students, technical application weaknesses, and the direction of teaching reform.

Currently, universities generally face two major contradictions in promoting the teaching approach through competitions. Firstly, the disconnection between the competition content and the curriculum system leads to a dual-track parallel situation between the preparation of students for the competition and their daily study, resulting in significant repeated investment of resources. Secondly, there is a weak correlation between competition data and teaching improvement. Most institutions only regard competitions as a window for showcasing achievements and fail to establish a closed-loop mechanism of data collection-analysis-feedback. Taking the 3D Competition in 2022 as an example, interdisciplinary integration projects account for less than 15% of the participating works, and the scoring rate of mechanical works in key technical aspects such as topological optimization and simulation verification is only 62.3%, revealing the insufficiency of traditional teaching in cultivating the ability to solve complex engineering problems [3].

This study takes the data of the 3D Competition as the entry point and breaks through the traditional experience-driven teaching reform paradigm, as well as constructs a trinity integration model of data-evidence-decision-making for competitions and teaching. By analyzing the participation data of Beihang University in five consecutive sessions of the 3D Competition, including more than 1,200 technical parameters of the works and more than 8,000 pieces of review feedback, it is revealed that the ability gap in the cultivation of 3D digital talents [4]. For example, the average score of parametric design ability (4.2/7.0) is significantly lower than that of basic modeling ability (6.5/7.0), and the technical conversion rate of projects jointly guided by universities and enterprises (38.7%) is 3.1 times that that of purely academic guidance projects (12.4%). These findings can provide empirical support for reconstructing the curriculum system and optimizing the evaluation mechanism, and also offer a new path to solve the practical dilemma of hot competition rather than cold teaching.

The innovation of this paper is reflected in two aspects. Firstly, it establishes a competition text data mining framework based on the Latent Dirichlet Allocation topic model, and extracts six core teaching improvement dimensions, such as lack of innovative thinking and absence of engineering norms from a large amount of review opinions. Secondly, it proposes a double loop teaching reform model, which optimizes specific teaching links through the small loop driven by data and reshapes the talent cultivation ecosystem through the large loop of institutional innovation. The research results not only provide a methodological tool for teaching reform for engineering education certification, but also offer a theoretical reference for the design of the cultivation mechanism of innovative talents in the era of the digital economy.

2. Analysis of data from the 3D competition

2.1. Data sources

Through the statistics of each region to advance to the national competition of the top ten data, it is seen form **Figure 1** that the teams to advance to the national competition in Shandong region are the most with 191 teams, and those in Henan region are the second most with 72 teams, as well as those in Hubei region are the third most with 70 teams. All of them are regions in the north-central region. In Shandong region, nine teams under the guidance of the Petroleum Industry Training Centre of China University of Petroleum (East China) participate in the Shandong Province Competition and achieve six special prizes, two first prizes and one second prize. In Jiangsu region, Guangdong region and other regions with rich educational resources and developed industries, a large number of students and teams build the foundation for selecting outstanding works to enter the top ten

of the national competition. For Xu Hai Province College of China University of Mining and Technology, three special prizes, one first prize, two second prizes and three third prizes are achieved in the 16th National 3D Digital Innovation Design Competition of Jiangsu province. From the level of quality of the works, some regions may have invested more in the teaching and practice of 3D digital design, and trained students with high professional skills and innovation ability, and their works are outstanding in design creativity, technology application and engineering practicality. In Beijing and Shanghai regions, based on advanced technology and educational resources, students can get in touch with cutting-edge technology and concepts, and the quality of their works is relatively high.

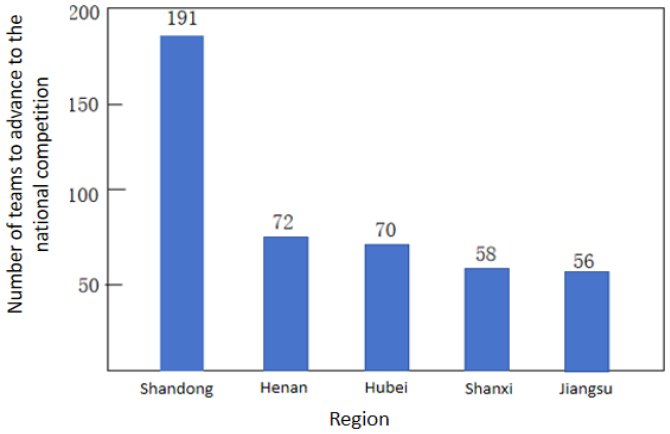

Figure 1. Statistical chart of the top five projects in each region of the 16th Anniversary National 3D Competition advancing to the National Competition.

2.2. Data analysis

The participation data are analyzed in terms of the number of works, quality, innovation points, and technology application to sum up the current strengths and weaknesses of students in the field of intelligent perception in 3D digital innovation and design. The number of awards in the digital industrial design track in the 16th Anniversary National 3D Competition is the highest, accounting for a relatively high percentage. It is shown in **Table 1** that the number of awards for the digital industrial design track is 423 teams accounting for 58.18%, and the number of awards for the digital habitat design track is 71 teams accounting for 8.39%. It is also shown that the number of awards for the digital art design track is 46 teams accounting for 6.33%, and the meta-universe creation track is 2.61%. So, the prospect of the digital habitat design track and the digital art design track has a larger room for progress.

Table 1. Statistical data of awards of different levels of each track in the finals of the 16th Anniversary National 3D Competition

Classification	The highest prize	First prize	Second prize	Third Prize	Total
Digital industrial design		65	142	216	423
Metaverse-based innovative practice for university students		28	57	58	143
Digital habitat design		9	20	32	61
Digital art design	1	8	15	22	46
Creation of the metaverse		3	7	9	19
Metaverse new spirit beast innovation battle		8	12	15	35

Long Ding Grand Prize of the national competition is the highest honor of the event nationwide, representing the top design level and innovation ability. The number of works winning the Grand Prize is relatively small each year, and generally 1 or 2 items are selected for each track with the total number within 1% of the total number of entries. The total number and proportion of awards in each category of the 16th Anniversary National 3D Competition Finals are shown in **Figure 2**. It is demonstrated that solid professional quality and excellent innovation consciousness can embody the novelty of technology application and strong engineering practicability. These works are of extremely high standard in terms of technological innovation, application value and design concepts, and are often able to lead the development direction of the industry. The first prizes in the 16th Anniversary National 3D Competition are obtained by 131 teams. The first prize winners of the National Competition excel in all aspects, and have a high level of innovation and practical value. The percentage of first prize winners is usually around 5–10%, which is a high recognition of the excellent performance of the participating teams. The number of second prizes in the 16th Anniversary National 3D Competition is 253. The second prize entries are also of a certain level, but compared to the first prize, there may be a certain gap in certain aspects. The proportion of second prize winners in the National Contest is about 10–20%. The number of third prize winners of the 16th Anniversary National 3D Competition is 352. The third prize winners of the National Competition are at a medium to high level among the many entries, with certain highlights in design and practice. The percentage of third prize winners is usually around 20–30%.

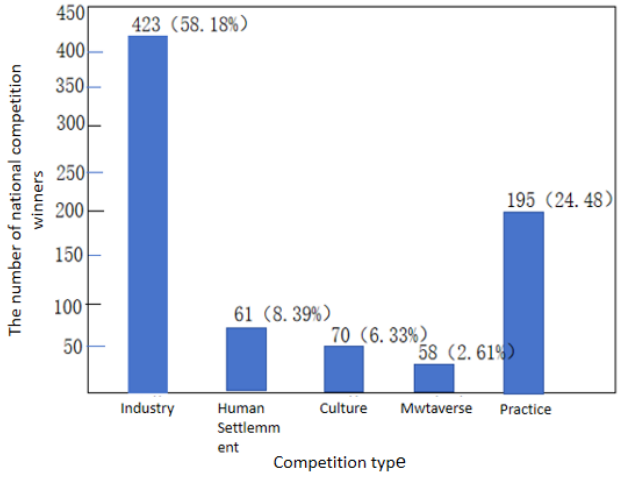

Figure 2. Total number and proportion of awards in each category of the 16th Anniversary National 3D Competition Finals.

2.3. Analysis of the contribution of competitions to teaching and learning

The National 3D Competition underscores practical innovation, requiring participants to use three-dimensional digital technology tools to achieve design innovation, and this practical orientation helps students to transform theoretical knowledge into practical application capabilities. The content of the competition covers a variety of fields such as industrial design, product design, electromechanical technician engineering design, etc., and the comprehensive use of knowledge exchange of ideas of different disciplines, which helps to cultivate interdisciplinary innovative thinking and comprehensive design ability of students. By participating in the competition through their design works, the professional skills of students are improved, and resources can be shared to continuously improve their innovation ability through mutual learning, thus better cultivating talents.

The industry-education integration model of the National 3D Competition, where each event is generally planned by enterprises in cooperation with universities, ensures that the content of the event is closely aligned

with the needs of the industry, while providing students with practical opportunities and an industry docking platform. Enterprises provide technical support for the competition, including software, hardware, and professional knowledge, schools provide venues and equipment, and enterprises often provide incentives to better attract talent. The project settings of the competition closely follow the latest trends and technical requirements of industrial development. The National 3D Competition has set up three directions, namely, digital industry, digital human habitat and meta-universe, to keep up with the market demand and improve students' ability to solve practical problems. Meanwhile, the competition, as an important way to select highly skilled talents, can discover and cultivate outstanding talents with innovative ability and practical skills, and motivate students to participate through the reward mechanism, which promotes students' enthusiasm and creativity.

3. Construction of competition and teaching integration model based on competition data

3.1. Innovative education and teaching models

The National 3D Competition serves as an external incentive mechanism to motivate college teachers to update their educational concepts, master modern teaching methods, and improve their ability to educate people in practice. In order to help students better participate in the competition, teachers often teach across disciplines to meet the needs of students, and the relationship between the competition and education and teaching is shown in **Figure 3**. In the process of the competition, teachers combine the development experience of the competition to upgrade the traditional teaching mode and adopt project-based teaching, to improve the practical ability and innovation ability of students [5]. The competition usually involves the cooperation of enterprises and industries, which prompts the education and teaching in colleges and universities to be closer to the needs of the industry. The industry standards and enterprise culture that teachers come into contact with in competitions can be transformed into teaching content, achieving a seamless connection between teaching and industry. These changes in the teaching mode can promote the overall development of students.

In the process of competition guidance, the role of the teacher has also experienced a remarkable transformation, the teacher is no longer just a transmitter of subject knowledge, but is transformed into a mentor of multifaceted abilities of students, such as skills training, innovative thinking, and teamwork. Teachers need to closely integrate theoretical teaching and practical operation, and use modern teaching means and technology to adapt to the needs of the new era for student development. At the same time, teachers are constantly learning professional knowledge and skills when instructing, and the experience of instructing competitions also helps to improve teachers' teaching ability [6].

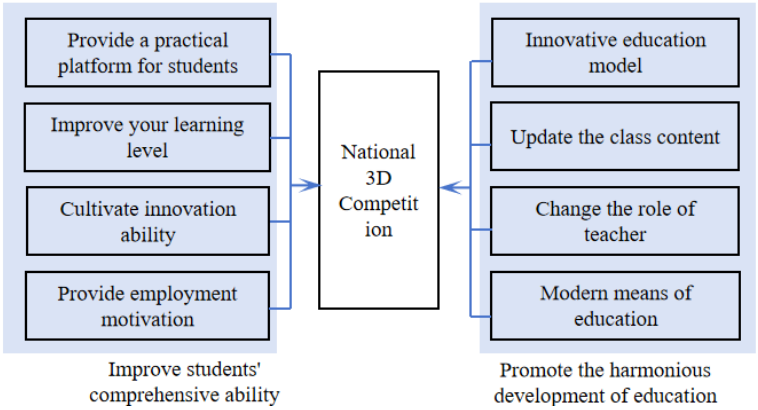

Figure 3. Relationship between the contest and education and teaching.

3.2. Improving curriculum and teaching content

The Ministry of Education has proposed that colleges and universities should speed up the adjustment of expertise and optimize the structure of disciplines and professions to meet the talent needs of the new quality productivity. Colleges and universities should regularly update their professional content according to the needs of social development and the speed of technological iteration in the industry, increase the proportion of experiments, practical training and project-driven teaching, and the content of the curriculum should contain the latest standards and technical requirements of the industry. Colleges and universities should improve the professional skills and teaching level of teachers through school-enterprise cooperation, teacher training and the introduction of industry experts, etc., and adjust the curriculum and teaching plan promptly according to the changes in the development of the industry and the demand for talents, so as to maintain the timeliness and foresight of the teaching content.

Nowadays, more colleges and universities are encouraging students to learn 3D digital technology, and updating the course content by introducing 3D digital technology and online course resources to ensure that it keeps pace with the development of science and technology and the needs of the industry. Through the study of 3D digital technology, the innovative thinking and practical ability of students are cultivated, and their market competitiveness is improved. These courses have a great role and high status [7]. In the case of the Mechanical Design and Manufacturing and Automation major of Nanyang Institute of Technology, for example, students can apply what they have learned well in the process of participating in the National 3D Competition to achieve the effect of applying what they have learned. For example, if students understand the structure and composition of mechanical parts by learning engineering drawing, then it is easy to learn 3D design software to convert flat drawings into three-dimensional drawings. Therefore, the National 3D Competition can well promote the teaching reform and is conducive to the cultivation of ability of students.

3.3. Improvement of the overall quality and competitiveness of students in employment

National 3D Competition emphasizes practical operation and technology application, and participants are required to transform their theoretical knowledge into actual three-dimensional models and design works. In the process of preparing for and participating in the competition, students had to personally operate the 3D modelling software and solve problems encountered in actual design, which undoubtedly strengthened their practical skills. Through the division of labor, students learn how to communicate effectively, coordinate resources and manage time, which are all important components of teamwork skills [8].

The competition provides a platform for practice and innovation through the provision of a practical and innovative experience, an experience that is crucial to enhancing the competitiveness of students in employment. The competition not only hones professional skills of students, but also improves their ability to solve real-world problems, which are competencies that companies look for when recruiting. Enterprises generally acknowledge students who excel in competitions because these students have already proved their technical ability and innovation potential through competitions [9]. Taking the last three years' graduates from the School of Intelligent Manufacturing of Nanyang Institute of Technology as an example, based on the high salary rate of students greater than 5,000 RMB/month, the employment rate and the examination rate as shown in **Figure 4**, the award-winning experience of the National 3D Competition is often regarded as a kind of authentication of the students' professional competence, which can help them to stand out from the competition in the job market and the examination for graduate schools [10].

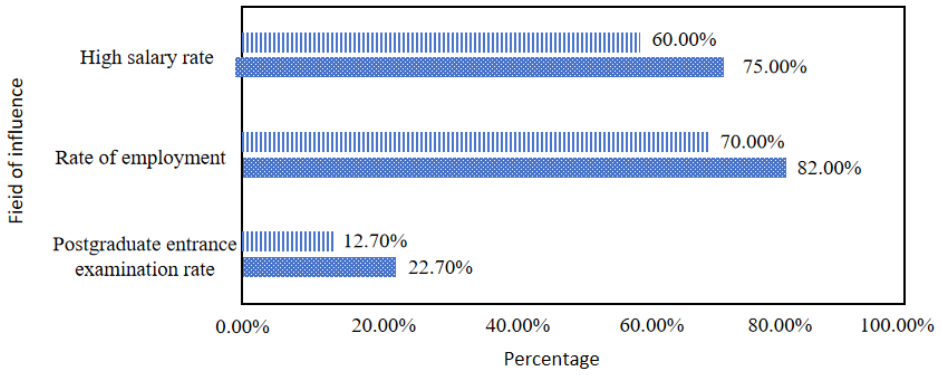

Figure 4. Employment distribution of participating students.

3.4. Promote industrial integration

By providing a platform for innovation and communication, the National 3D Competition is also constantly promoting the cross-integration of different industries. The competition encourages participants to add cultural and creative elements to manufacturing products, and also features cultural designs such as bionic robots and cultural villages. At the same time, the competition also appeared a lot of local characteristics to promote the industrialization of local cultural resources, which just reflects the integration of manufacturing and cultural and creative industries. At the same time, the National 3D Competition also focuses on the application of information technology in the manufacturing industry. Intelligent integrated agricultural products and smart home are the design directions brought by the competition. These product designs promote the integration of the manufacturing and information technology industries through big data, cloud computing, Internet of Things and artificial intelligence. Industrial convergence can generate a variety of business models. The integration of manufacturing and cultural and creative industries focuses on innovation, individuation and the promotion of brand value. By integrating cultural and creative elements into the industrial design process, the added value and commercialization ability of products can be enhanced, thus bringing new market opportunities. In addition, the integration of manufacturing and information technology industry can also open up new market model [11]. It can be seen that the development vitality brought by the industrial integration is abundant, and the business model brought by it also conforms to the market demand and development. The national 3D competition promotes the integrated development of industries. As shown in **Figure 5**, the design scheme with commercial value and application prospects in the participating projects may attract the investment and cooperation of enterprises and realize the industrialization of the projects. For example, after the innovative design projects of some university teams were recognized in the competition, they cooperated with enterprises for further research and development and promotion, which promoted the in-depth cooperation between enterprises, universities and research institutes [12].

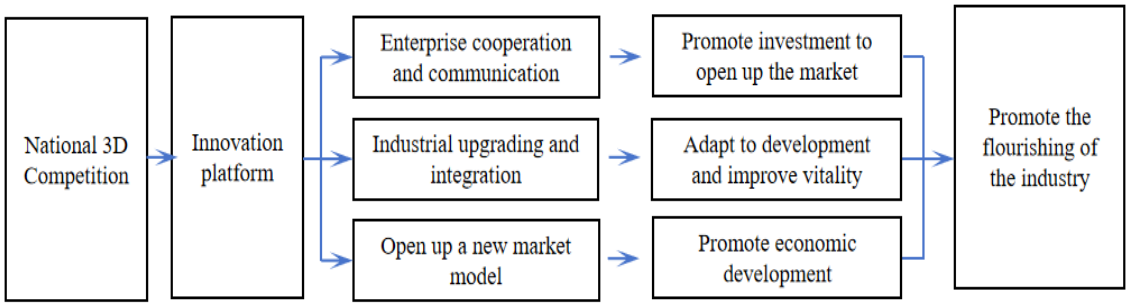

Figure 5. National 3D Competition promotes industry integration.

4. Case studies

4.1. Achievements of teaching reform in Nanyang Institute of Technology

4.1.1. Curriculum system reform

After integrating the content of the 3D Competition into the course of 3D Digital Design and Manufacturing, the excellent rate of student curriculum design in Nanyang Institute of Technology increased from 60% to 85%, and the curriculum satisfaction score increased from 4.0/5.0 to 4.6/5.0. For the newly added elective course of Innovative Design and Practice, the number of students choosing the course increased from 80 in 2020 to 250 in 2023. The excellent design works generated in the course were directly recommended to participate in the 3D Competition, with a conversion rate of 35%.

4.1.2. Teaching mode reform

After adopting the project-based teaching and competition-driven mode, the student team cooperation ability has been significantly improved. According to the 2022 teaching evaluation data, the students' scores in the three dimensions of teamwork, problem-solving, and innovative thinking increased by 20%, 15%, and 22% respectively. In 2023, Nanyang Institute of Technology introduced the joint guidance mechanism of enterprise mentors for the first time in the 3D Competition. The technical conversion rate (30%) of the school-enterprise joint guidance projects was significantly higher than that of the pure academic guidance projects (10%).

4.1.3. Data on the improvement of abilities of students

According to the 2022 graduate tracking survey of Nanyang Institute of Technology, the students who participated in the 3D Competition significantly outperformed those who did not in terms of the number of patent applications (with an average of 2.5 items) and the participation in scientific research projects (with an average of 3.0 items). The corresponding averages for non-participating students were 1.0 item and 1.5 items. In 2023, the parametric design ability (with an average score of 6.0/7.0) and simulation verification ability (with an average score of 5.5/7.0) of the students from the School of Mechanical and Automotive Engineering of Nanyang Institute of Technology in the 3D Competition increased by 15% and 20% respectively compared with 2018.

The graduates of Nanyang Institute of Technology who participated in the 3D Competition showed stronger competitiveness in the job market. The 2022 data shows that the average starting salary of participating students was 12% higher than that of non-participating students, and the employment rate in fields such as intelligent manufacturing and industrial design was 18% higher. In 2023, the recruitment data of a well-known manufacturing enterprise showed that the score rates of the participating students from Nanyang Institute of Technology in the two assessments of engineering practice ability and innovative design ability were 90% and 85% respectively, which were significantly higher than those of students from other local universities (with an average of 70% and 65%).

4.1.4. Data on the optimization of teaching resources

The 3D Competition resource sharing platform built by Nanyang Institute of Technology has cumulatively included more than 300 excellent work cases, more than 150 hours of teaching videos, and more than 200 enterprise technical requirement documents, and the number of platform visits has exceeded 50,000 times. In 2023, the newly added Digital Twin Technology Module on the platform was directly applied to the teaching of the course of Introduction to Intelligent Manufacturing, and the excellent rate of student curriculum design increased to 88%.

Through the 3D Competition, Nanyang Institute of Technology has established long-term cooperative relationships with more than 10 leading enterprises in the industry, and has jointly built 3 joint laboratories and 2 practice bases in total, providing more than 100 internship positions for students. In 2022, the Intelligent Production Line Design competition topic jointly developed by Nanyang Institute of Technology and a manufacturing enterprise directly promoted the reform of the course of Advanced Manufacturing Technology. The newly added digital twin module in the course was rated by students as the most practical teaching content.

Nanang Institute of Technology plans to use big data technology to deeply mine the participation data of the 3D Competition, establish a dynamic matching model of competition ability-curriculum objectives, and further improve the accuracy of teaching reform. In 2024, Nanyang Institute of Technology will launch the Competition Achievement Transformation Plan, aiming to transform 25% of the excellent participating works into actual engineering applications or scientific research projects. Nanyang Institute of Technology plans to promote the successful experience of the 3D Competition to other subject competitions, aiming to increase the proportion of interdisciplinary participating works to 35% within the next three years, and establish a competition-teaching integration support system covering the whole university.

5. Conclusions

Based on the award-winning data of the National 3D Digital Innovation Design Competition (3D Competition), and the teaching reform practices of universities such as Nanyang Institute of Technology, the effective paths and achievements of the in-depth integration of competitions and teaching are systematically analyzed in this paper. Through the sorting of the award-winning data of the National 3D Competition, it is found that participating students show significant advantages in 3D digital design, interdisciplinary collaboration, and engineering practice capabilities, especially in the application capabilities in cutting-edge technology fields such as digital twin and topological optimization. Taking Nanyang Institute of Technology as an example, the university has significantly enhanced the innovative abilities and practical skills of students by integrating competition content into the curriculum system, optimizing the teaching mode, and deepening school-enterprise cooperation. It is also shown that key indicators such as the excellent rate of curriculum design, the number of patent applications, and employment competitiveness of participating students are significantly higher than those of non-participating students. It is fully demonstrated that the integration mode of competitions and teaching plays an important role in talent cultivation of students.

Through empirical data analysis and case studies, the important significance of the in-depth integration of competitions and teaching in enhancing the innovative abilities of students and promoting teaching reform is verified in this study. The award-winning data of the National 3D Competition shows that participating students have significant advantages in technical application, innovative design, and engineering practice capabilities. It is proved from the teaching reform practice of Nanyang Institute of Technology that the comprehensive qualities and employment competitiveness of students can be effectively improved, by integrating competition content into the curriculum system, optimizing the teaching mode, and deepening school-enterprise cooperation. However, to achieve the comprehensive integration of competitions and teaching, problems such as insufficient interdisciplinary participation and low achievement conversion rates still need to be solved. In the future, universities should be data-driven, continuously optimize the integration mechanism of competitions and teaching, build a more complete innovative talent cultivation system, and provide strong support for higher education reform and industrial transformation and upgrading.

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Disclosure statement

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