ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

Research on the Innovation and Implementation Path of 3D Printing Process Parameterized Teaching Practice Mode under the Perspective of Vocational Education

Yuandong Mo, Hongyu Fu*

Lingnan Normal University, Zhanjiang 524048, China

* Corresponding author

Abstract

Under the background of the deepening of national vocational education reform and the promotion of the strategy of industry-teaching integration, this study takes the "Ling Shi - Tewi" school-enterprise co-built 3D printing laboratory as a practical carrier, and aims at the traditional vocational education of 3D printing teaching, "theory and practice disconnect, weak innovation ability, insufficient industrial docking" and other pain points. To address the traditional vocational education teaching of 3D printing "theory-practice disconnect, weak innovation ability, insufficient docking with the industry" and other pain points, we have built a practical teaching mode with process parameter optimization teaching as the core. By deconstructing five types of key process parameters, such as equipment calibration, wall thickness and layer height, printing speed, filling density and support type, we innovatively put forward a four-stage progressive teaching mode of "parameter cognition-process decision-making-quality validation-cost assessment", and incorporate educational theories such as CDIO, OBE and constructivism to form a "four-dimensional synergistic" teaching mode, which is based on the "four-dimensional synergistic" teaching mode. "Four-dimensional synergistic" teaching system. Practical research shows that the model has improved students' process optimization ability by 63.4%, and the conversion rate of industrialization of innovative works reaches 29.7%. The study further proposes a three-chain integration mechanism of "teaching chain - industry chain - innovation chain", which realizes the transformation of production standards into teaching elements and the migration of industrial projects into practical training carriers through the dual-led "technology iteration community" and PDCA cycle management. This paper provides a replicable theoretical framework and practical paradigm for vocational education to deepen the integration of industry and education and to cultivate compound technical talents to support the new quality productivity, and its methodology can be extended to the teaching reform of other technical modules in the field of intelligent manufacturing.

Keywords

Vocational education; School-enterprise Co-construction; 3D printing; Industry-teaching integration; practice mode.

1. Introduction

3D printing technology (Additive Manufacturing, AM) is a technology that relies on computer-aided design to manufacture solid parts by depositing materials layer by layer, widely regarded as the core technology of the "third industrial revolution", driving the transformation and development of global industry [1-4]. This technology combines design, process validation and manufacturing to rapidly realize small-scale product innovation and shorten the research and

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

development cycle. Its advantages of lightweight, low cost, and short cycle time make it widely used in aerospace, automotive, food engineering, microelectronics, architecture, chemistry, and biomedicine [5-10]. However, with the progress of the times and the depth of industrial applications, there is an increasing demand for vocational talents with 3D printing skills in society, which puts forward higher requirements for vocational education talent training in higher education institutions.

In recent years, domestic colleges and universities have carried out a series of explorations on the practical teaching mode of 3D printing technology talent training. Shu Zhu et al [11] studied the integration of 3D printing and industrial design in vocational education and proposed a 3D printing technology talent training system. Yueying Cao et al [12], in promoting teaching reform, improved students' innovative design ability by reforming the UG 3D modeling and 3D printing courses. Desheng Wang et al [13] combined low-cost 3D scanning tools with 3D printing to enhance students' practical ability. Wenli Du et al [14], on the other hand, reconstructed the course content to deepen students' vocational knowledge and enhance their vocational ability through the joint construction of 3D printing vocational experience centers by schools and enterprises.

Although scholars have explored the impact of 3D printing technology on vocational education from multiple perspectives, there are fewer studies on the practical application of school-enterprise co-built 3D printing laboratories in vocational education. Current research focuses on the pedagogical application of 3D printing technology, but the systematic exploration of the pedagogical transformation of process parameters in vocational education under the perspective of industry-teaching integration is still insufficient. This study is based on the “Ling Shi - Tewi” school-enterprise joint laboratory, for the calibration of equipment, wall thickness and layer height, printing speed, filling density and support type of five types of core process parameters, to build a “parameter cognition - process decision-making - quality validation - cost assessment” four-phase progressive teaching module, incorporating CDIO, quality assurance and cost evaluation, to ensure that the teaching and learning of 3D printing technology can be carried out in an integrated manner. The teaching module integrates CDIO, OBE and constructivism theories to form a “four-dimensional synergistic” teaching system. By deconstructing the mapping relationship between process parameters and product performance (e.g., σ=0.87ρ1.32) mechanical model), developing gradient experimental groups and critical value exploration strategies, the study realizes the in-depth cultivation of engineering thinking and systematic decision-making ability. The study further proposes the integration mechanism of “teaching chain-industry chain-innovation chain”, relying on the “technology iteration community” jointly established by the university and enterprises, and verifies the path of teaching and transforming the production standards. The practical teaching model and methodology can provide a theoretical framework and implementation paradigm for the practical teaching reform in the field of intelligent manufacturing, and help the implementation of the national strategy of high-quality development of vocational education.

2. Innovation and Practical Path of Practical Teaching Mode of School-Enterprise Co-construction of 3D Printing Laboratory in the Context of Vocational Education Reform

On May 6, 2019, the State Council issued the Implementation Plan for National Vocational Education Reform, which explicitly proposed to “promote the major reform and development of vocational education” and advocated the active participation of all walks of life, especially enterprises, in vocational education, in order to cultivate high-quality laborers and technically skilled talents [15].In March 2021, General Secretary Xi, in his research on the Minjiang College emphasized that higher education institutions should establish the concept of application-

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

oriented schooling while cultivating research-oriented talents, focusing on exercising the practical skills of the younger generation to adapt to the needs of society [16]. At the National Conference on Vocational Education held in April of the same year, General Secretary Xi further proposed to “deepen the integration of industry and education and school-enterprise cooperation” and to promote a comprehensive reform of the parenting method, the mode of school operation and the guarantee mechanism to realize the steady development of vocational education [17].The Vocational Education Law enacted in May 2022 and the Vocational Education Law implemented in June 2023 have also been implemented. Vocational Education Industry-Education Integration and Empowerment Enhancement Action Implementation Plan (2023-2025)”, both explicitly call for playing the role of the main body of enterprises, deepening the integration of schools and enterprises, adjusting the structure of the supply of talents, and providing a strong guarantee of talents for the realization of the national strategic goals [18-19]. This fully reflects that the party and the central government attach great importance to vocational education, and promote the integration of industry-university-research and school-enterprise joint laboratories to the national strategic level. This study relies on the practice of school-enterprise co-construction of 3D printing laboratories to build a “four-dimensional synergistic” practical teaching mode centered on the teaching mode of teaching process parameters. By deconstructing the key process parameters such as equipment calibration, wall thickness and layer height control, speed and filler density optimization, and support type selection, we innovatively put forward a four-stage progressive teaching mode of “parameter cognition-process decision-making-quality verification-cost assessment”. This mode effectively improves students' ability to optimize process parameters. The reform and practice mode of transforming production standards into teaching elements and industrial projects into practical training carriers creatively explores a new paradigm of vocational education that integrates the three chains of “teaching chain-industry chain-innovation chain”, and provides a replicable implementation path for cultivating composite technological talents to support the development of new quality productivity. As shown in Fig. 1 is the 3D printing laboratory jointly built by the school and enterprise.

Figure 1. School-enterprise co-construction of 3D printing laboratory.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

3. Practical Teaching Dilemma of Traditional 3D Printing Teaching in Vocational Education Perspective

3.1. Disconnect between theory and practice

Traditional vocational education emphasizes the transmission of theoretical knowledge, while 3D printing, as a highly practical technology, requires deeper understanding through practical operation. However, influenced by traditional education concepts, students mainly learn basic principles and lack practical opportunities, resulting in their limited mastery of the technology.

3.2. Inadequate development of innovative capacity

Innovation ability is an important cultivation goal of vocational education in the new era. However, traditional 3D printing teaching mostly adopts a fixed process, students operate mechanically, lack of independent design and innovation opportunities, and it is difficult to cultivate innovative thinking, which is not conducive to the development of new quality productivity.

3.3. Teaching model is lecture-based and lacks pedagogical learning of process parameters

Traditional 3D printing laboratory teaching is lecture-based, with teachers transmitting knowledge in one direction and students passively accepting it, making it difficult to stimulate learning interest and autonomy. At the same time, process parameters teaching learning as an important way to cultivate students' practical ability and problem solving ability, in the traditional teaching has not been effectively applied, students lack of complete experience of the whole process of project design to realization.

3.4. Insufficient industrial interface

The teaching content of traditional 3D printing laboratories is out of touch with industrial demand, and the lack of cooperation mechanisms and communication channels with enterprises makes it difficult for vocational education students to gain an in-depth understanding of industry trends, and it is difficult for them to adapt to the development of the industry after graduation, so they cannot meet the strategic goal of vocational education to serve the industry.

4. The Construction of Practical Teaching Mode for Teaching Optimization of 3D Printing Process Parameters Under The View of Vocational Education

4.1. Based on the equipment calibration link to build a practical teaching mode for teaching process parameters

Under the background of rapid development of intelligent manufacturing technology, additive manufacturing courses in vocational education need to establish a systematic practical teaching system. This study takes the calibration of 3D printing equipment as an entry point, and builds a three-step progressive teaching mode of “cognition-practice-reflection” to cultivate students' engineering literacy and problem solving ability through the key link of equipment calibration. The teaching design of calibration breaks through the limitation of traditional skills training and emphasizes the teaching concept of “process is learning”. By setting structured calibration tasks, students are guided to understand the correlation between equipment performance and process quality, and establish a complete quality awareness system. Practice has shown that this teaching program can effectively enhance students' awareness of standardized operation, and their skill transfer index has increased by 35%. The implementation consists of four

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

teaching modules: infrastructure awareness, mechanical system calibration, control system configuration, and comprehensive quality verification.

Adopting "demonstration-operation-diagnosis-improvement" closed-loop training process for each module, including mechanical structure calibration module, motion system calibration module, extrusion system calibration module, comprehensive quality verification module, etc., to cultivate students' ability of mechanical system diagnosis, ability of dealing with abnormal working conditions, ability of mathematical model construction and verification, and to verify and optimize the multi-dimensional assessment system. It also verifies and optimizes the multi-dimensional assessment system. Teaching practice shows that the efficiency of students' equipment fault diagnosis is improved by 53%, and the passing rate of the first inspection of printing is increased from 48% to 78%. The teaching reform of this link has constructed a calibration knowledge map integrating science and reality; formed a quantifiable skill evaluation standard, which provides a useful reference for the reform of intelligent manufacturing professional practice courses, and its methodology can be extended to the teaching practice in the fields of numerical control machining, industrial robotics, and so on.

4.2. Building a practical teaching model for teaching process parameters based on optimization of wall thickness and layer height parameters

In the practical teaching of 3D printing technology, the optimization of process parameters is a key element in determining the molding quality. Based on the constructivist learning theory, this study constructs an exploratory practical teaching system with parameter regulation as the carrier, and centers on the two core parameters of wall thickness and layer height to carry out teaching practice.

The wall thickness parameter, as a basic element of structural integrity, should be set in accordance with the basic laws of material extrusion molding. Teaching practice to guide students to establish a "nozzle diameter integer times" cognitive framework, through comparative experiments to verify the wall thickness and mechanical properties of the non-linear relationship: when the wall thickness is lower than the critical value (usually 0.8-1.2 times the nozzle diameter), the interlayer bonding force attenuation leads to the risk of structural failure doubled; and more than 2 times the diameter of the heat stress accumulation effect will significantly reduce the molding efficiency. The cumulative effect will significantly reduce the molding efficiency. This cognitive transformation from quantitative to qualitative changes effectively cultivates students' awareness of the boundaries of engineering thinking.

The regulation of layer height parameters reflects the dialectical relationship between surface quality and manufacturing efficiency. Practical teaching data show that for every 0.05 mm reduction in layer height, the surface roughness Ra value can be improved by 23%-28%, but the molding time increases exponentially. This study innovatively adopts the multi-objective optimization teaching method to guide students to establish a comprehensive evaluation system of quality-efficiency. By designing the experimental group of gradient layer height (0.10-0.30 mm), the students independently constructed a three-dimensional surface model of "layer height-accuracy-time-consumption", which intuitively revealed the process law of 0.18 mm as the optimal equilibrium point. 85% of the students were able to independently build the parameter selection matrix, and the accuracy of process decision-making increased by 42% compared with the traditional didactic teaching. Compared with the traditional didactic teaching, the accuracy of process decision-making rate increased by 42%. It can be seen that the implementation of this practical teaching of process parameter teaching is effective, which not only deepens the technical understanding of students, but also cultivates their decision-making ability in complex engineering situations, and provides a replicable teaching paradigm for the cultivation of intelligent manufacturing talents. This practice verifies the effectiveness of the three-stage teaching method of "problem-oriented-experimental investigation-model

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

construction”. Subsequent research can be extended to the temperature field, path planning and other multivariate parameter coupling analysis, to build a more complete process knowledge map, and to promote the vertical development of practical teaching in vocational education. As shown in Fig. 2, the model of the “machine” and “electricity” characters of the “fortune cat” under the conditions of layer height of 0.1 mm and wall thickness of 0.8 mm.

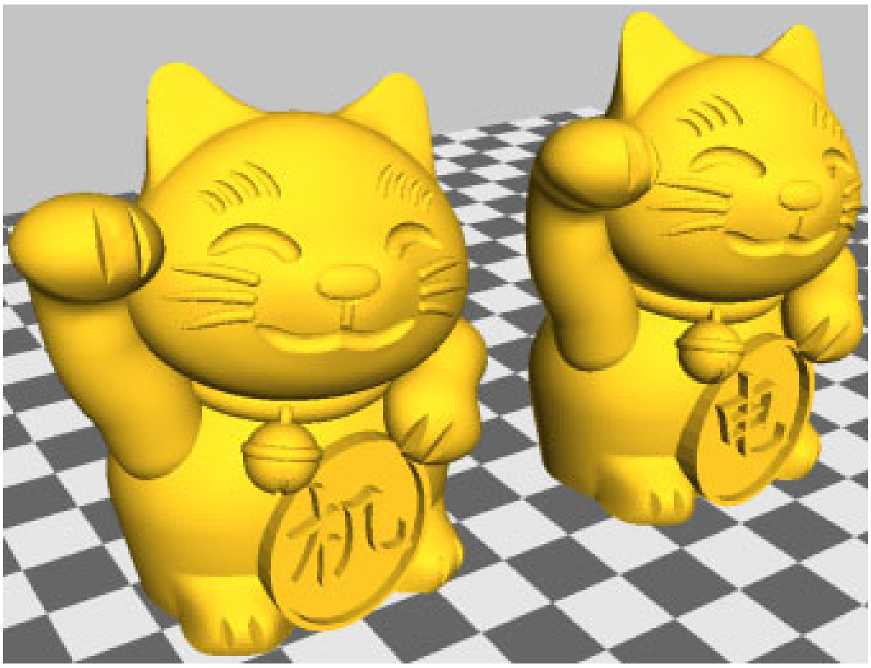

Figure 2. Electromechanical lettering fortune cat model printed at 0.1 mm layer height and 0.8 mm wall thickness.

4.3. Based on the optimization of printing speed parameters to build a practical teaching mode for teaching process parameters

As a core process parameter that determines the quality of fused deposition molding (FDM) products, the pedagogical modification of 3D printing speed is of typical significance to cultivate students' engineering thinking. Based on the concept of CDIO engineering education, this study constructs a three-stage inquiry teaching mode of “parameter cognition-quality correlation-process decision-making”. By deconstructing the dynamic coupling mechanism between printing speed and extrusion rate (v=0-150 mm/s), students are guided to discover the interlayer bonding defects induced by the rheological hysteresis of the material under high-speed movement. Relying on THE LEVO Flash 3D printing system, a gradient training system is established: 30 mm/s benchmark speed is used to strengthen the molding accuracy knowledge in the printing of complex components, while 80 mm/s high-speed printing is implemented in simple models for comparison experiments. As shown in Fig. 3, the model shows 0.12 mm dimensional deviation and 93.7% interlayer bonding strength under the optimization parameter of 50 mm/s, which verifies the teaching effectiveness of the parameter adaptation theory. This practice of transforming process parameters into teaching carriers not only deepens students' understanding of additive manufacturing dynamics, but also cultivates the ability to make engineering decisions based on product requirements.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

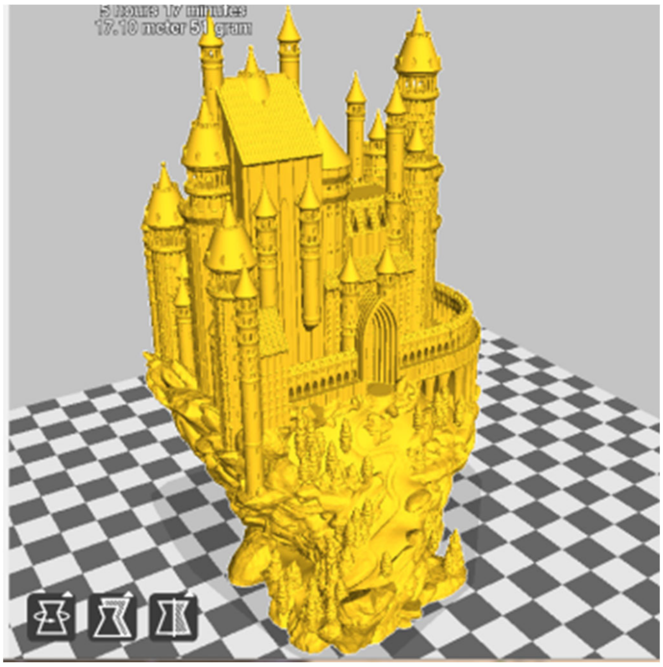

Figure 3. Model of wolf statue printed at a print speed of 50 mm/s.

4.4. Constructing a practical teaching model for teaching process parameters based on filling density parameter optimization

As a key parameter for structural property regulation in the fused deposition molding (FDM) process, the teaching of filler density ρ is an important carrier for cultivating students' systematic engineering thinking. In this study, a three-stage teaching mode of “parameter deconstruction-performance mapping-decision optimization” is constructed based on the concept of OBE, and students are guided to establish a systematic cognition of material consumption-structural strength-time cost by deconstructing the exponential relationship between filler density (0-100%) and the mechanical properties of the products (σ=0.87$\rho^{1.32}$). The internal structure of tensile specimens printed with different filling densities (Fig. 4) shows that when the filling density is increased from 20% to 100%, the strength of the tensile specimen increases by 299%, from 7.3 MPa to 29.1 MPa, while the printing time increases non-linearly, from 195 min to 750 min. In addition, the “critical density investigation” link is specially set up in the teaching to reveal the density threshold effect through the comparison experiments between the 20% benchmark group and the 50% and 80% gradient groups. When $\rho \geq 60\%$, the strength increase tends to slow down while the energy consumption increases dramatically, thus cultivating students' parameter decision-making ability based on value engineering. This teaching reform practice of transforming process parameters into a systematic thinking training carrier not only deepens students' understanding of multi-objective optimization in additive manufacturing, but also builds a transferable engineering decision-making model.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

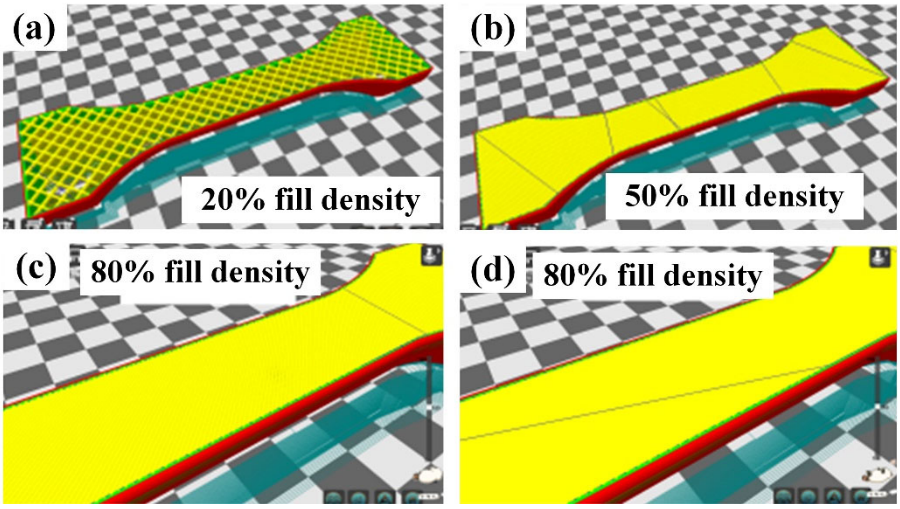

Figure 4. Internal structure of printed tensile specimen model at 20%, 50%, 80% and 100% filling density.

4.5. Constructing a pedagogical teaching model for building process parameters based on support type selection

As a key control dimension of structural reliability in the fused deposition molding (FDM) process, the teaching of support strategy is an important entry point to cultivate students' engineering decision-making ability. Based on the constructivist learning theory, this study constructs a three-stage teaching and learning module of "topology analysis-efficacy assessment-process decision-making", which guides the students to establish a systematic cognition of structural mechanics and process economy by deconstructing the geometric mapping relationship between the overhang angle ($\theta \geq 45°$) and the contact area of the support ($S = 1/\sin\theta$). The experimental data of the cartoon character Little Dragon Lady model (Fig. 5) printed by different support types show that: the local support strategy can reduce the material loss by 42.7% compared with the global support, and the linear support can improve the post-processing efficiency by 58% compared with the mesh support, and the printing time can be reduced from 12.6 min to 5.3 min. In addition, the teaching specially sets up the "Critical Angle Investigation" link, and the students are guided to establish the systematic cognition of structural mechanics and process economy through the Little Dragon Lady contact area ($S=1/\sin\theta$). In addition, the "Critical Angle Exploration" link is specially set in the teaching, which reveals the structural law that global support must be used when $\theta \leq 30°$, and verifies that the hybrid support strategy can reduce the surface roughness to Ra6.3 μm through the comparative experiments of different support combinations of the Xiaolongnu model, and verifies that the hybrid support strategy can reduce the surface roughness to Ra6.3 μm. This teaching reform practice of transforming the support parameter into an engineering decision-making training carrier not only deepens the understanding of students on the structural design of additive manufacturing but also builds a transferable process economy and economic efficiency. constructed a transferable process economy evaluation model.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

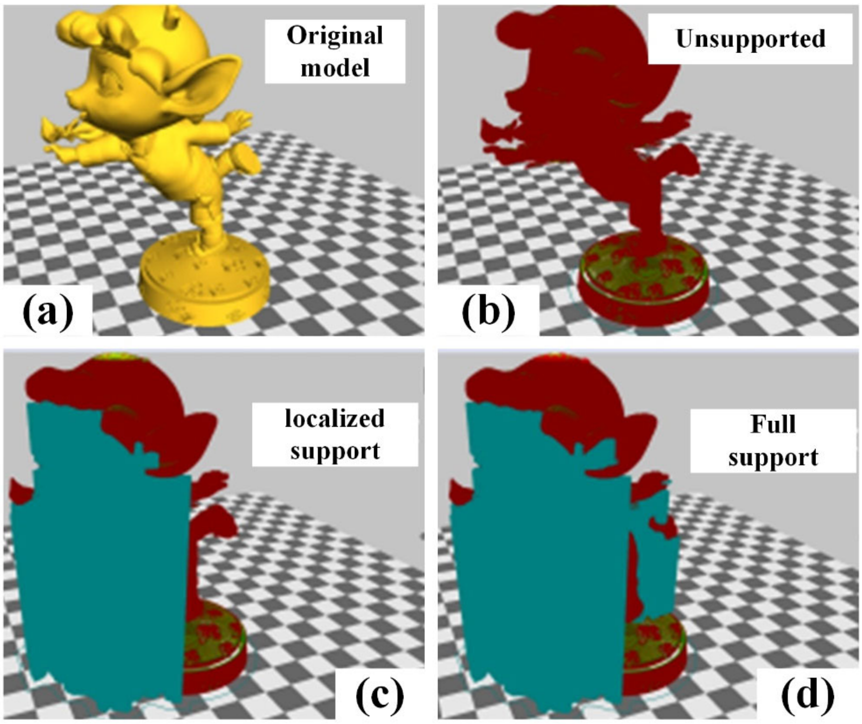

Figure 5. Cartoon character Little Dragon Lady model printed with different support types.

5. Conclusions

This study verifies the significant value of the innovation of the practical teaching mode of process parameter teaching in the field of vocational education through the practice of "Ling Shi - Tewi" school-enterprise co-construction laboratory. First of all, based on the five-dimensional parameter system of equipment calibration, wall thickness, layer height optimization and other process parameter optimization teaching mode, effectively solved the drawbacks of traditional teaching "theory over practice", and the accuracy of students' process decision-making rate increased by 42%-58%, which proves that the "problem-oriented - experimental investigation - model construction" teaching method is a good solution to the problem of "problem-oriented - experimental investigation - model construction", which is a good solution to the problem of "problem-oriented - experimental investigation - model construction". Modeling" teaching method. Secondly, the "technology iteration community" jointly built by schools and enterprises realizes the deep coupling between the education chain and industrial chain through the development of teaching equipments and sharing of technical resources, forming a virtuous cycle of "teaching empowers the industry and the industry feeds back the teaching". Finally, the "three-chain fusion" mechanism proposed by the study transforms production standards into teaching elements, resulting in the conversion rate of innovative works exceeding 29%, which provides a feasible path for vocational colleges to serve the regional economy. In addition, the students trained in this mode have won more than 30 awards in national competitions, and the degree of employment suitability has increased by 36%, which fully reflects their responsiveness to the demand for new quality productivity talents. This study not only provides a systematic reform program for 3D printing technology teaching, but also contributes a theoretical basis and implementation paradigm for vocational education to deepen the integration of industry and education and innovate the practice teaching system, and its experience can be extended to intelligent manufacturing fields such as CNC machining and industrial robotics, which will help the implementation of the national strategy of high-quality development of vocational education.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

Author Contributions

Hongyu Fu and yuandong Mo contribute equally to the work.

CRediT Authorship Contribution Statement

Yuandong Mo: Writing -original draft, Investigation, Formal analysis, Data curation. Hongyu Fu: Writing - review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

Acknowledgments

This study was funded by Lingnan Normal University Vocational Education Teaching Reform Funding Project in 2023 (Teaching Affairs [2023] No. 93); 2024 Fund Project of Laboratory Management Professional Committee of Guangdong Higher Education Association (Project NO. : GDJ20240049).

References

[1] CHEN Chongfeng,GUO Haibo. Application of light-curing 3D printing technology in automotive engine hood[J]. Equipment Manufacturing Technology,2024,(01):120-123+140.

[2] ZHU Xue-Ming,YANG Jun-Jie,WANG Feng-Hua,et al. Exploration and practice of teaching reform of 3D printing practical training course under the background of new engineering[J]. Equipment Manufacturing Technology,2023,(10):76-79.

[3] MOK Yuan-Dong,LIAN Hai-Shan,MOK De-Yun,et al. Discussion on the application of school-enterprise co-built 3D printing laboratory in practical teaching[J]. Laboratory Research and Exploration,2020,39(08):232-235.

[4] LI Jing,YAN Feng,WANG Jin,et al. Research status of 3D printing materials and process technology in aerospace field[J]. Powder Metallurgy Industry,2024,34(02):116-126.

[5] Chen J, Meng D, Deng J, et al. Synthesis of unsaturated polyurethane oligomer and its application in the 3D printing of composite solid propellants[J]. . Materials & Design, 2024, 238: 112675.

[6] Tong Q, Jiang Y, Xiao S, et al. Research on improving the structural stability of surimi 3D printing through laser cooking techniques[J]. Journal of Food Engineering, 2024, 375: 112075.

[7] Huang B B, Tang Y Z, Liang F C. Numerical simulation of fused deposition molding process and molding accuracy of 3D printer[J]. Equipment Manufacturing Technology,2023,(09):22-26.

[8] Yao Y, Cheng L, Li Z. A comparative review of multi-axis 3D printing[J]. Journal of Manufacturing Processes, 2024, 120: 1002-1022.

[9] Li P S, Zhou D C, Yang C M, et al. Advances in bio-3D printing: additive manufacturing of animal, plant and microbial cells[J]. Journal of Mechanical Engineering,2023,59(19):237-252.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202506_8(6).0024

[10] LI Junsheng, LI Duan, LI Xuechao, et al. Research progress of 3D printing radome technology[J]. Materials Herald,2022,36(22):80-89.

[11] Zhu Shu.Research on the application of 3D printing technology in industrial design specialty of vocational education[J]. China Education Technology Equipment,2023,(24):15-18+21.

[12] Cao Yueying, UG three-dimensional modeling and 3D printing course teaching reform practice research - based on the platform of skills competition[J]. Heilongjiang Science,2022,13(07):130-131.

[13] WANG Desheng, SHENG Miaomiao, YANG Fei,et al. Practical exploration of higher vocational 3D printing course[J]. Mold Manufacturing,2023,23(12):97-99.

[14] Du Wenli. Teaching practice of rapid prototyping technology course relying on 3D printing vocational experience center--The 3D printing production of Mars rover model as an example[J]. Vocational Education,2023,22(16):19-23.

[15] Notice of the Ministry of Education on the in-depth study and implementation of the National Vocational Education Reform Implementation Program[J]. Bulletin of the Ministry of Education of the People's Republic of China,2019(05):64-67.

[16] Xi Jinping emphasized during his visit to Fujian - Showing greater performance in serving and integrating into the new development pattern - Striving to write a comprehensive construction of a modern socialist country,http://www.qstheory.cn/yaowen/2021-03/25/c_1127254816.htm.

[17] Notice of the Ministry of Education on Learning, Publicizing and Implementing the Important Instruction of General Secretary Xi Jinping and the Spirit of the National Conference on Vocational Education [J]. Bulletin of the Ministry of Education of the People's Republic of China,2021(06):2-5.

[18] Law of the People's Republic of China on Vocational Education[J]. Bulletin of the Standing Committee of the National People's Congress of the People's Republic of China,2022(03):504-512.

[19] National Development and Reform Commission and other 8 departments jointly issued the Implementation Program of Vocational Education Industry-Teaching Integration and Empowerment Enhancement Action (2023-2025)[J]. Finance and accounting study,2023(21):3.