ISSN 2663-8169 Vol. 7, Issue 12: 1-7, DOI: 10.25236/IJNDE.2025.071201

Research on Teaching Reform of Intelligent Manufacturing Technology Course Based on Outcome-Based Education from the Perspective of 3D Printing

Xin Li[a,*], Hongling Wu[b], Panpan Zhang[c]

Suqian University, Suqian, China
[a]nanlixin@nuaa.edu.cn, [b]90008@squ.edu.cn, [c]18156@squ.edu.cn

Abstract: *Under the background of emerging engineering education, cultivating the innovation and entrepreneurship abilities of engineering students can help them smoothly carry out their graduation projects and win competitive advantages in the job market. In the current context of Outcome Based Education (OBE), the talent training model for the Intelligent Manufacturing Engineering major lacks practical education on the integration of intelligent manufacturing technology and intelligent manufacturing theory in entrepreneurship and innovation. Graduates of traditional mechanical engineering majors find it difficult to adapt to the development trend of industrial intelligence in the employment environment, resulting in a mismatch between the number of applied talents trained by schools and the talents needed by enterprises. Therefore, how to cultivate applied talents for the intelligent manufacturing system is an urgent problem that needs to be solved in the training goal of intelligent manufacturing engineering professionals. To explore a new talent cultivation model for intelligent manufacturing engineering, this paper focuses on 3D printing technology in the basic course of intelligent manufacturing and uses a beetle's hind wing for reverse modeling teaching. The exploration of teaching reform in this course will enhance the application and practical abilities of students majoring in intelligent manufacturing engineering.*

Keywords: *Intelligent Manufacturing Engineering; 3D Printing; OBE; Teaching Reform; Reverse Modeling*

1. Introduction

The development of science and technology represents the comprehensive strength of a country. One of the reasons for the tense international atmosphere has always been the competition for energy. However, manufacturing is the economic pillar of a country and an important manifestation of industry competitiveness. The rapid development of the Chinese economy has brought about a conflict between the natural environment and the country's demand for resources. The revitalization of the manufacturing industry is urgent, and Made in China 2025 has set development goals for the manufacturing industry. Moreover, intelligent manufacturing technology is also one of the important development directions, which requires universities to develop talent training models for intelligent manufacturing majors. At present, the talent cultivation goal in the field of mechanical engineering in Chinese undergraduate colleges is to cultivate students with basic knowledge and application abilities in mechanical design, manufacturing, electromechanical engineering, and automation [1]. Moreover, they are also exposed to courses closely related to the manufacturing industry, such as industrial robots, artificial intelligence, mechanical design, and fundamentals of intelligent manufacturing technology, which enables them to effectively utilize their mechanical knowledge they have learned.

To cultivate students' practical and innovative entrepreneurial abilities, OBE based teaching methods are often introduced into the classroom by teachers to facilitate students' efficient acceptance of new knowledge. This teaching method is mainly based on the outcome-based education (OBE) concept. The OBE concept is an educational concept based on students' ultimate learning outcomes, with its core being the design, implementation, and evaluation of teaching activities around students' learning outcomes [2, 3]. The teaching objectives under the OBE concept are the results achieved by students in the educational process, which requires a clear understanding of the importance of classroom teaching effectiveness for students. Teachers organize course content, teaching, and evaluate course outcomes based on talent

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development goals. Based on the OBE concept, it can explain the effects that students need to achieve during their education period, and teachers can design personalized teaching according to individual differences of each student [4]. Outcome oriented education emphasizes that everyone can 'succeed'. This traditional sense of success not only refers to achieving good grades, but also includes students' ability to develop core competencies in life and work during the learning process. Therefore, education focuses more on cultivating students' comprehensive qualities and abilities [5].

With the deepening of teaching reform, the OBE teaching concept has become a synonym for courses within the scope of higher education disciplines both domestically and internationally. It is important to describe the different possible sources of results used in different contexts, as it will have positive implications for the theory and practice of curriculum research. Meanwhile, it will provide curriculum theorists with knowledge on how curriculum sources are reflected in OBE curriculum development [6]. Although incorporating the OBE concept into engineering education can achieve good results, the question is whether teachers have the ability to implement the OBE concept. Exploring the impact of OBE on engineering education based on psychological content, it is found that the concept of OBE can be beneficial in the evaluation, implementation, reflection, and curriculum design of engineering education [7]. But it is necessary to provide further training for teachers in specific fields. Based on the theory of innovative composition and the OBE concept, the teaching mode of the New Nurse Innovative Nursing Practice Workshop was designed [8]. It was found that combining theory with practice in the teaching process fully mobilized students' thinking, interest, and subjective initiative. Students' creative thinking and problem-solving abilities have not only been improved, but their teamwork skills, literature review skills, and communication abilities have also been enhanced to varying degrees. Based on the artificial intelligence indicators of labor demand related to the industry in OBE vocational education applications, creative vocational education models and performance-based vocational education models have been developed [9]. The organizational model of vocational education influenced by OBE explains the differences related to creativity and performance.

Applying the OBE concept to the teaching of intelligent manufacturing engineering courses and exploring its application effects is a new exploration of teaching reform. 3D printing technology is one of the core modules in the basic course of intelligent manufacturing, which has an impact on multiple industries such as automotive, engineering, healthcare, aerospace, sports, fashion, and education. In the field of education, 3D printing is used in many different areas such as pharmacy, mathematics, biology, chemistry, art education, graphic design, engineering, and even in early childhood and special education. As teachers' knowledge of 3D printing technology increases, their intention to integrate 3D printing technology into the classroom will also increase. Future information and communication technology teachers are exploring new ideas for integrating 3D printing into teaching, as well as their evaluation system for the 3D modeling and printing courses provided. The results indicate that most new teachers have sufficient competence in the course and are satisfied with the smooth integration of 3D printing technology into teaching activities [10]. Based on 26 teachers and 1501 students who used 3D printing for engineering and mathematics learning in the context of paleontology, this study examined the impact of teachers' beliefs and the integration of 3D printing in science classrooms on students' motivation in science, technology, engineering, and mathematics [11]. A 3D printing course and teaching method that can be practically applied in public education courses has been proposed [12]. Students can easily create products through the use of 3D programs and cultivate creativity through this product design process. This research result will contribute to the development of future educational courses.

The current teacher teaching program does not provide sufficient advanced manufacturing theories for trained students with the necessary professional knowledge and skills to use intelligent manufacturing in the classroom. This is because intelligent manufacturing is an emerging discipline, and the definition method for intelligent manufacturing is not yet mature. Although in terms of training mode, classroom design is mainly guided by the "Made in China 2025" development strategy [13], industrial internet of things, robotics and automation, sensors, and intelligent manufacturing execution systems are introduced as core courses in the field of intelligent manufacturing engineering. Given the limited research on the reform of basic courses in intelligent manufacturing, this paper combines the reverse modeling process of insect wing design with 3D printing technology based on the OBE concept to explore teaching methods for 3D printing content in intelligent manufacturing basic courses that can be practically applied in public education courses. This reform method can cultivate students' data analysis and decision-making abilities, enabling them to understand and apply the potential of big data in manufacturing environments.

ISSN 2663-8169 Vol. 7, Issue 12: 1-7, DOI: 10.25236/IJNDE.2025.071201

2. Fundamentals of Intelligent Manufacturing Course

2.1 Basic Teaching of Intelligent Manufacturing

Intelligent manufacturing engineering is a branch discipline of mechanical engineering, mainly formed by interdisciplinary integration of multiple disciplines into a comprehensive applied knowledge system. This major not only requires students to have a solid foundation in theoretical knowledge, but also demands that they have strong practical abilities. In recent years, the teaching of intelligent manufacturing fundamentals has often focused on theoretical knowledge, while neglecting the cultivation of practical abilities. There is a situation where many students have rich theoretical knowledge but weak practical abilities. In classroom teaching, teachers usually make presentation slides (PPT) of knowledge points in the textbook, interspersed with some pictures or videos, and occasionally ask students questions. Students are in a passive learning state and have low enthusiasm for learning. The experimental teaching of intelligent manufacturing has not formed a unified system. The basic experimental teaching of intelligent manufacturing is mainly based on computer simulation, and the exploration of experimental cases also needs to be carried out in depth. Computer simulation experiments are mostly demonstrated by teachers in advance, and students rarely take the initiative to conduct them. Moreover, some students have a negative attitude and have limited mastery of the actual content. Therefore, the previous teaching mode of intelligent manufacturing basic courses is not conducive to cultivating students' hands-on ability, innovation ability, and practical ability.

2.2 3D Printing

3D printing is an important chapter in the basic course of intelligent manufacturing, which is the process of creating physical objects from digital models, also known as additive manufacturing. Fused Deposition Modeling (FDM) is currently the most widely used 3D printing technology in industry. 3D printing technology includes 3D scanning, reverse modeling to create 3D digital models, and layering the models and using 3D printers for production. Reverse engineering 3D models is the most important process in 3D printing, which can be achieved by scanning existing objects with a 3D scanner or combining point cloud data collected from various angles using photogrammetry. Reverse modeling software such as Imageware, Geomagic Studio, and UG are used for creating 3D models. After the 3D model is created, the data format should be converted to STL file type, which is the standard format for 3D printing. Importing STL file into slicing software (3D printer software) to set printing properties. Slicing software generates a G-code file, which can be transferred to a 3D printer for printing via USB/Wi Fi connection or external storage card (flash drive or SD card).

For parts with complex mechanical structures, 3D printed prototypes that can effectively display the details of these components can solve abstract thinking problems by providing real-time simulation of the actual motion of these mechanical structures through the printed parts. In addition, when it comes to specific testing of materials and structures subjected to different loads in courses such as mechanical design, material mechanics, and theoretical mechanics, 3D printing can transform the problems discussed by teachers on the blackboard and the questions raised in student textbooks into real-time models that students can experience, and enable students to see the behavior of these structures under specific loads. Printed parts can even undergo tension or compression, bending, buckling, or complex types of mechanical load testing in the laboratory. The teaching reform based on the OBE concept in courses such as 3D printing technology, industrial robots, CNC machine tools, and artificial intelligence will provide various important training opportunities for teachers in the field of intelligent manufacturing engineering to widely apply these technologies in the educational environment of mechanical engineering.

3. Intelligent Manufacturing Fundamentals Course Using 3D Printing as an Example

3.1 Materials and Methods

This paper is guided by the concept of bio-inspired and uses beetle wings for reverse modeling design and 3D printing production. Beetle samples are captured from bamboo forests and their hind wings are cut off from their bodies. To ensure that the corrugations on the surface of the hind wing are not damaged as much as possible during the cutting process, it is necessary to use tweezers to clamp the root and leading edge of the wing. Stick the unfolded rear wings on the foam board to wait for natural air drying. Before conducting a 3D scan on the hind wing sample, the ventral and dorsal sides of the hind wing were sprayed with imaging agents. The advantage of spraying imaging agent is to prevent the scanner's light

ISSN 2663-8169 Vol. 7, Issue 12: 1-7, DOI: 10.25236/IJNDE.2025.071201

source from penetrating the thinner area of the wing, thereby causing the scanning point cloud data in that area to be missing. As shown in Figure 1, the 3D scanner is used to scan gradually from the ventral and dorsal sides of the hind wing along the wing root to the wing tip. Finally, the point cloud data file of the scanned wings is saved in *. asc format.

Figure 1 3D scanning captures point cloud data

The course of 3D modeling and printing is a compulsory course for students majoring in intelligent manufacturing engineering, which is taught in their first and third year respectively. Therefore, when learning the 3D printing operation in the basic course of intelligent manufacturing, they have the reserve ability of 3D modeling and 3D printing knowledge. The 3D modeling and printing course in paper is usually a practice oriented course aimed at enabling future teachers in the field of intelligent manufacturing to use CAD software to design teaching materials and explore teaching reforms in the field of intelligent manufacturing engineering using 3D printing as an example.

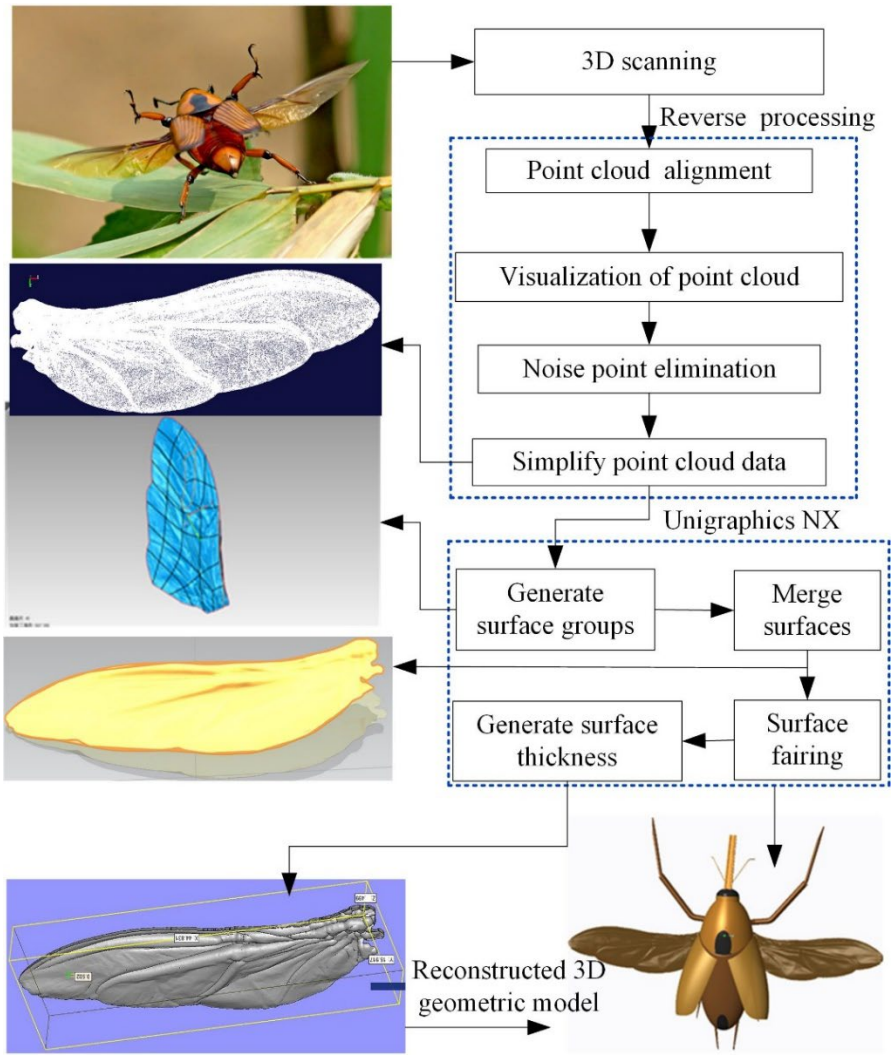

Figure 2 Reverse reconstruction of point cloud data

ISSN 2663-8169 Vol. 7, Issue 12: 1-7, DOI: 10.25236/IJNDE.2025.071201

Imageware software and UG software were selected as reverse modeling software, which is a powerful 3D modeling and rendering software suitable for visual effects artists. Within the course scope, the basic modeling tools for operating Imageware software were explained to students. Import point cloud data into Imageware for coordinate system calibration. The sample needs to be scanned multiple times to obtain all the point cloud data on the surface. During the scanning process, it is inevitable that other irrelevant points will be scanned in, so it is necessary to simplify the point cloud data and remove the noise points mixed in during scanning. The extra points on the dorsal and ventral sides of the wings are called noise points, which are unrelated to the wings. At this point, the merged surface creates an overall surface model that is a sheet without thickness. The model needs to be thickened by saving the surface model in *. igs file format and importing it into UG software. The complete reverse modeling process is shown in Figure 2.

3.2 3D Printing Production

In the course, students learned how to reverse model objects in software. Later, they learned how to set up printing and operate the 3D printer. At the same time, some students have started working on their subject competition projects, which will become teaching materials used in educational contexts. Two weeks later, they completed the design and produced the teaching materials. Because there is only one 3D printer, students in the class are divided into small groups and allowed to print in their spare time. Therefore, each group can export the digital model of insect wings created from the material to an STL file for printing. As shown in Figure 3, one of the physical models is made of white resin, which is used as the printing material.

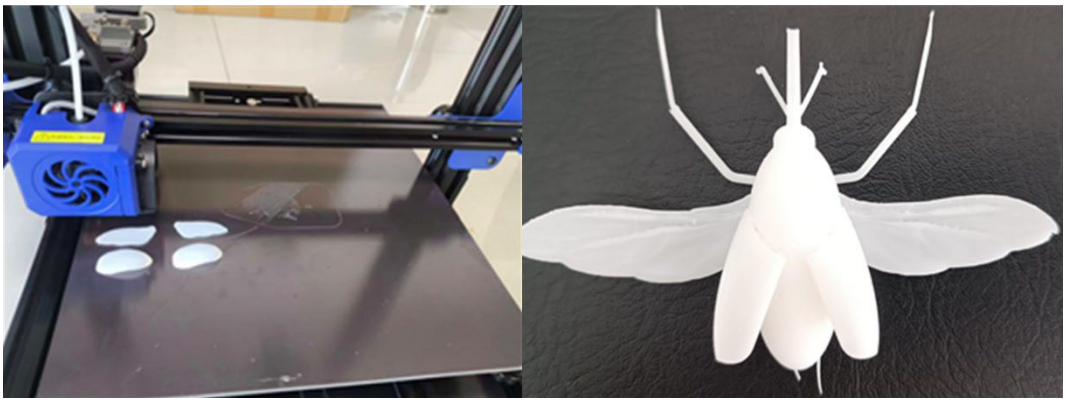

Figure 3 3D printing of beetle after reverse modeling

3.3 Result Analysis

This study attempts to explore the teaching reform based on the OBE concept in the basic course of intelligent manufacturing. The classroom exploration and evaluation will focus on the reverse reconstruction and printing of 3D models of insect wings. Based on the 3D printing process of insect wings, the understanding of 3D printing technology and the views of future intelligent manufacturing teachers on using 3D printers to produce teaching materials are analyzed. This course aims to introduce the effectiveness of integrating 3D printing into the classroom for future intelligent manufacturing engineering teachers and enhance students' understanding of the opportunities and challenges of integrating 3D printing technology into education.

According to the interview survey, more than half of the students in this study hold a positive attitude towards this new teaching method, and more students are willing to promote this method to other courses in the field of intelligent manufacturing engineering. The teaching of intelligent manufacturing engineering courses can be strengthened by using teaching methods similar to 3D printing. When students are allowed to freely use 3D printing technology in their course work, they become more excited and enthusiastic. Therefore, teachers have a responsibility to integrate teaching methods similar to 3D printing into the curriculum by involving students in different activities.

The most important aspect of teaching based on the OBE concept is to cultivate students' personal abilities, allowing them sufficient time to explore relevant knowledge and design solutions. In addition, the teaching plan also emphasizes students' autonomy and initiative: (a) Through the 3D scanning, reverse modeling process, and installation of 3D printing software involved in the teacher's 3D printing

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process, students can understand the secrets behind 3D printing technology. (b) The students were grouped to explore a series of techniques from reverse modeling of insect wings to 3D printing of physical objects, calculated their working time, and obtained corresponding data. (c) Students model and validate the feasibility of the model themselves. (d) After completing the 3D printing of the physical object, students observed the surface morphology of the beetle on site and attempted to improve the accuracy of reverse modeling to obtain a model that is closer to the real beetle wings. At the same time, teachers and other group members were invited to provide opinions and suggestions on the improvement effect.

Finally, both the teachers and students involved in this project believe that the application of OBE concept in the basic teaching of intelligent manufacturing is significantly more effective than traditional courses. They unanimously believe that it is important to focus on cultivating practical and innovative abilities in the curriculum. Moreover, this teaching method is practical in existing teaching plans, as it is more conducive to cultivating students' comprehensive abilities and nurturing the "innovative talents" needed for the new era.

4. Conclusion

Improving the teaching level of the department of intelligent manufacturing engineering, cultivating intelligent manufacturing talents needed by the new era society, and enhancing students' self-learning ability, practical ability, innovation ability are important goals of current mechanical engineering talent cultivation. This study first introduces a series of explorations by other scholars on teaching method reform, taking 3D printing content as an example, and proposes a teaching method for intelligent manufacturing basic courses based on the OBE concept. From 3D scanning of insect wings to reverse modeling design and final 3D printing production of physical objects, it is all the process that students participate in and efficiently complete. The purpose of this operation method is to explore the application effect of this teaching method and familiarize teachers and students with the teaching process. Through interviews with teachers and students, it has been preliminarily proven that this teaching method has certain effectiveness. In addition, it is important to use more teaching experiments to demonstrate the effectiveness of the proposed method in this article. It is necessary to demonstrate whether the teaching methods proposed in this paper can be applied to other courses, and if so, what adjustments should be made to promote this. In future teaching, we will draw on the theories and experiences formed in OBE practices at home and abroad, and further explore and construct learning models that are in line with the actual situation of Chinese education.

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ISSN 2663-8169 Vol. 7, Issue 12: 1-7, DOI: 10.25236/IJNDE.2025.071201

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