The Role of Digital Twin Technology in Promoting Practical Teaching under the Epidemic

Sen Tao[1], Junye Cai[2], Qing Wu[3], Lili Sha[2,*]

[1]East China University of Science and Technology, Shanghai, 200237, China

[2]Shanghai Ocean University, Shanghai, 201306, China

[3]East China University of Science and Technology, Shanghai, 201306, China

*Corresponding author: Rhine_sha@163.com

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Abstract: With the new engineering putting a greater emphasis on intersectionality, practicability, and comprehensiveness, engineering education places a premium on practical teaching via extensive experimentation. However, the post-epidemic era will undoubtedly have a significant impact on comprehensive experiments, which will be extremely detrimental to China's efforts to build world-class engineering schools. How to promote practical teaching in an epidemic situation has become a pressing issue that must be addressed. This article primarily discusses how to reduce the design scheme and process route through the use of digital twin technology, how to adjust and optimize the cost of prototype production, how to improve the overall quality of engineering students through digital design, and how to eliminate the risk associated with experimental teaching operations, all of which can be helpful for future research into new engineering fields.

1. Introduction

The industrial and technological revolutions on a global scale are resuming. Germany, China, and the United States have proposed “Industry 4.0,” “Made in China 2025,” and “Industrial Internet”[1]. Advanced technologies such as the Internet of Things and industrial robots provide robust technical guarantees for intelligent manufacturing[2]. As a result, the Ministry of Education promotes the development of new engineering disciplines aggressively [3]. The disconnect between experiments conducted in various professional courses in colleges and universities has become more acute, and comprehensive experiments are urgently needed. On the other hand, post-epidemic colleges and universities are unable to conduct offline instruction. These impediments suffocate the growth of However, the digital twin concept can assist in resolving these issues. A digital twin is a process of simulation that utilizes a physical model, sensor updates, operation history, and other data to complete the mapping in virtual space [4]. As a result, the digital model does not impede the overall quality of engineering students. Not only can the digital twin be used to adjust the design scheme, but it can also be used to replace the actual electromechanical experimental device with a high risk factor, obviating the need for experiments. The promotion of digital twins is anticipated to significantly alleviate the current epidemic of engineering student practical teaching issues. Also hoped for is the promotion of this technology in the educational field in order to improve the practical teaching of new engineering concepts and techniques.

2. Three Uses of Digital Twin Technology in Practical Teaching

The concept of a digital twin first appeared in 2003. Professor Grieves makes the suggestion in relation to product lifecycle management (PLM). It is referred to as a “information mirror model” or “digital twin” in the literature. NASA introduced the concept of digital twins into its space technology roadmap for the first time in 2010. NASA intends to use digital twin technology to conduct a comprehensive diagnosis and prediction of flight systems[6]. Numerous research findings regarding the use of digital twin technology in the field of world-class engineering education have been published in recent years. Due to the epidemic that has lasted more than two years, engineering students are unable to conduct offline practical teaching activities, which creates a disconnect between experiments and impedes the cultivation of new engineering talents. As a result, it is critical to investigate the impact of digital twin technology on practical teaching and then to spread the concept of practical teaching across colleges and universities.

2.1 Reduce Prototype Production Costs by Optimizing Design and Process Routes

The digital twin technology provides a new idea for colleges and universities to develop experimental equipment according to local conditions. For example, the school wishes to develop a set of cargo handling machinery that is equipped with a timing belt driven by a speed-regulating motor, a truss-type mechanical arm adsorption device, and a PLC for the purpose of instructing students in electromechanical transmission control and other related topics. A virtual debugging stage is completed by changing the physical properties and parameters of the model in real time during the simulation stage after it has been established as a digital twin. Some useful data are fed back from the simulation of the digital twin, such as the suitable range of motor speed, the size of the mechanical arm adsorption force, the number of control I/Os, etc., so as to complete the adjustment and optimization of the design scheme and process route, and achieve the purpose of reducing the number of prototype iterations.

In addition, digital twin technology based on the human-information system to assist personnel in analysis and decision-making and human-machine collaborative control, can realize the parallel of three-dimensional design, program design, and electrical schematic drawing of experimental equipment, which greatly shortens the cycle of experimental equipment being put into use and saves manpower and material resources. Carry out digital twin network teaching activities in the form of online lectures and online learning to ensure. Guarantee that in the case of a postponement of the school's opening, “the suspension of classes will not stop teaching, and the suspension of classes will not stop learning”. Good teaching effect has been achieved.

2.2 Improve the Comprehensive Quality of Engineering Students through Digital Design

The carrier for digital twin technology is a 5G distribution network and VR virtual simulation technology, which promotes the integration of physical and virtual space and changes the form of learning places, the way of presenting learning content, the form of learning exchange between teachers and students, and the form of learning evaluation. There are numerous critical differences that contribute to the unique learning characteristics of the digital twin era[7]. For instance, experimentation with digital twin technology can be used to develop experimental equipment designed by engineering students that can fully utilize the PID control system, sensors, work logs, and other data to achieve multidisciplinary and multi-scale learning. Students majoring in mechanical design, manufacturing, and automation can use a set of electromechanical experimental equipment provided by the department to complete a comprehensive experiment involving various knowledge points in mechanical design, electromechanical drive control, PLC, sensors, and configuration monitoring software. It cultivates students' engineering practice abilities as well as their ability to innovate in their fields of study while ensuring the comprehensiveness and intersection of teaching. This method also addresses the issue of independence and disjunctness between experiments conducted in various professional courses at colleges and universities, which aids in the construction of a student-centered digital twin hybrid smart teaching system, as well as extensive research on the digital twin teaching environment, integration organization, and platform construction of multidimensional teaching information.

Instead, if there is an issue with the practical teaching during a semester and the engineering students do not have a sufficient understanding of a particular process, the outcomes may be chained. Due to the epidemic, class of 2018 students at the East China University of Science and Technology majoring in mechanical design, manufacturing, and automation were only able to conduct online metal processing practice. In comparison to animation, the simulation performed by the simulation platform was unsatisfactory in terms of teaching results. As a direct result, the learning of the fundamentals of mechanical manufacturing in the following semester is significantly hampered, which is extremely detrimental to the development of the professional manufacturing direction in the long term. For the 2018 East China University of Science and Technology mechanical design, manufacturing, and automation students, as shown in Table 1, the epidemic has caused a delay in the practical teaching hours and course credits for the students.

Table 1 Practical Teaching Hours and Course Credits Delayed by Epidemic

Curriculum	Class Hour	Credit
Metalworking Technology Internship	160	4
Mechanics of Materials	6	3.5
Engineering Materials	6	2
University Physics Experiment(Part2)	48	3
Mechanical principle	8	3.5
Electrical and Electronics Experiments	24	1
Mechanical experiment	24	1

2.3 Eliminate the Danger of Experimental Teaching Operation

University laboratory safety accidents have occurred on occasion in recent years, indicating that there are still some issues with laboratory safety management. We investigate the causes of laboratory safety accidents in colleges and universities between 2010 and 2020 and the need to incorporate digital twin technology into practical teaching in order to address this issue. As illustrated in Fig. 1, 21 laboratory accidents occurred in Chinese universities between 2010 and 2020, resulting in six deaths and numerous injuries [7]. With China's education system continuing to develop, colleges and universities place a greater emphasis on the development of students' practical abilities and practical control abilities. As the proportion of experimental practice courses has increased, this has resulted in intensive laboratory personnel, frequent use of experimental instruments and equipment, and so forth. Additionally, experimental personnel have a low level of safety awareness, limited safety knowledge and response capabilities, and laboratory management systems that are behind the times.

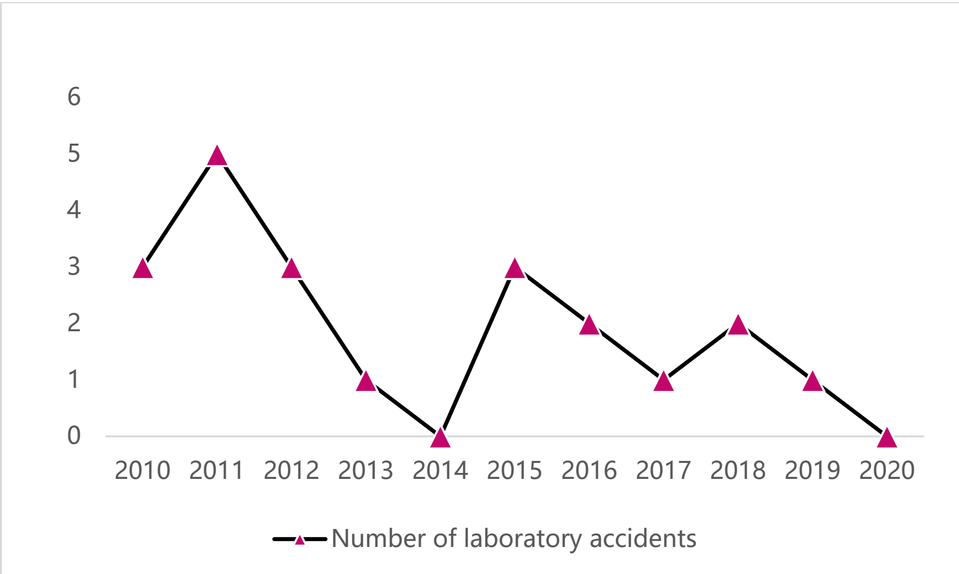

Figure 1: Laboratory Accidents of Universities from 2010 to 2020[8]

Due to the existence of such issues, laboratory safety accidents have occurred more frequently in recent years, jeopardizing the campus's stability and safety [9]. As a result, we can significantly reduce the occurrence of laboratory safety accidents in colleges and universities by implementing an experimental teaching method based on the internal causes and mechanisms of safety accidents. For instance, the electromechanical experiment of mechanical design, manufacturing and automation, requires a voltage of 220 volts, and the electromechanical experimental equipment's circuit is complicated. Conducting structural experiments carries the risk of an electric shock. The application of digital twin technology enables the learning of electromechanical equipment from the global to the local level without the risk of electric shock or overspeeding power machinery. It teaches students through the use of e-learning materials, course videos, the Internet, and other information technologies, as well as the flipped classroom and technology-enhanced creative interactive teaching (TEAL) modes. It significantly reduces risk during experimental operations, allowing for the expansion of the learning space for digital information technology [10].

3. Conclusions

By evaluating the cost savings associated with prototype production due to the adjustment and optimization of the design scheme and process route, the enhancement of the overall quality of engineering students through digital design, and the elimination of the danger associated with experimental teaching operations, it can be demonstrated conclusively that, in the context of the epidemic, digital design provides a significant boost to practical teaching through twinning technology, and an increasing number of colleges and universities are allocating resources to this endeavor. As a result, it is both feasible and necessary to implement a practical teaching model based on digital twins in the post-epidemic era.

Authors' Contributions

This paper is completed by Sen Tao, Junye Cai and Qing Wu, Lili Sha as the corresponding author of the dissertation, give constructive opinions on the advanced nature, originality, rationality of experimental design and method, reliability and rigor of conclusions, etc.

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