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Enhancing the Pedagogy of Theory-Practice Integration in the Machining Technology and Programming

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Abstract: This study proposes innovative teaching strategies for the course of "Machining Technology and Programming", aiming to improve teaching quality and promote students' comprehensive skills development by updating teaching materials, strengthening practical teaching facilities, and introducing virtual factory software. Especially in the online and offline teaching mode, emphasis is placed on the deep integration of theory and practice, using virtual factory software to simulate real work environments to compensate for the shortcomings of physical practice bases. Teaching strategies based on students' abilities are crucial in stimulating their interest. Through process oriented evaluation, comprehensively assess students' abilities and cooperation spirit, combine information technology and Industry 4.0 background, cultivate CNC machining professionals, and meet the strategic needs of Made in China 2025. At present, there is a problem of theoretical and practical disconnection in CNC machining technology programming education. The "theory practice integration" teaching mode proposed in this study provides effective reference for promoting the improvement of undergraduate education through a cyclic process of practice and understanding.

Keywords: Machining Technology and Programming; Theory-Practice Integration Teaching Method; Virtual Factory Software; Process Evaluation.

1. Introduction

The course "Machining Technology and Programming" holds a significant position in the curriculum of applied undergraduate engineering programs and vocational colleges in China. With the advancement of information technology, this course is crucial for nurturing future professionals in the industrial sector. However, Wang (2019) pointed that current teaching faces several challenges such as varying student abilities, outdated instructional materials, an imbalance between theoretical and practical instruction, a shortage of bilingual instructors, and inadequate coordination between courses. These issues impact teaching quality and hinder comprehensive skill development among students.

This study aimed to explore methods for developing practical course resources by establishing curriculum research groups, enhancing practical training facilities to create more hands-on opportunities. Additionally, it sought to leverage both online and offline teaching methods by introducing virtual factory software to simulate real work environments complementing physical practice bases' limitations. Furthermore, differentiated assignments based on student capabilities are proposed to stimulate learning interest and motivation. Shifting from outcome-based assessment to process-oriented evaluation will comprehensively assess students' learning abilities and collaborative spirit while exploring new approaches that integrate theory with practice aiming at improving students' overall practical skills. The impetus for this study stemmed from the rapid evolution of information technology alongside national policies supporting applied talent development. Through these strategies, it is anticipated that the quality of instruction for "Machining Technology and Programming" can be significantly enhanced resulting in graduates who possess both theoretical knowledge and practical skills necessary to meet Industry 4.0's demand for CNC machining professionals contributing towards China Manufacturing 2025.

Gong (2019) mentioned that applied undergraduate engineering programs along with vocational colleges play a pivotal role as vital grounds for cultivating talents within society; thus making CNC machining technology programming a key focus area within these institutions' curricula especially amidst rapid technological advancements where CNC machines are increasingly valued within various industries further driving demand for skilled professionals from vocational colleges specializing in CNC machining technology programming. For vocational colleges specifically focusing on cultivating expertise in CNC machining technology programming presents both opportunities as well as challenges necessitating identification of existing pedagogical gaps while actively engaging students' enthusiasm towards learning thereby elevating their overall competencies.

This paper aimed to address the primary issues encountered during the teaching process of Machining Technology and Programming course and understand students' acceptance and satisfaction with current curriculum teaching. It also discussed measures aimed at strengthening the integration between theoretical concepts and practical applications, with the hope of eliciting valuable insights and recommendations within academic circles.

1.1. Literature Review

In application-oriented undergraduate or vocational undergraduate education, influenced by the teaching mode of the general education subject system, traditional curriculum teaching mode is still followed in teaching. Wang (2019) discovered that although there is practical training in teaching, the focus is still on the complete teaching of the theoretical system of the subject, and there is a disconnect between theory and practice, without a true organic combination. The teaching model of "theory practice integration" is a

combination of professional theory and practice, which not only achieves the combination of theory and practice, but also stimulates students' interest in active learning. It breaks the boundary between traditional theory and practical teaching, combines theory with practical teaching, starts from perceptual knowledge, strengthens intuitive teaching, improves students' cognitive ability, and becomes a scientific and effective teaching model for cultivating skilled talents. The integration of theory and practice teaching model is an effective teaching model for undergraduate students.

1.1.1. Practice and theory complement each other to promote teaching

An (2014) believed that students first practice and then learn theoretical knowledge with questions. The purpose of learning theoretical knowledge is to solve the problems encountered in the previous practice process and prepare for the next practice link in teaching. The whole teaching process is practice - understanding - practice - understanding again, until mastery. To realize the practice-centered technology courses actively serve the new teaching mode of CNC Machining Technology and Programming courses.

1.1.2. The teaching mode combining theory and practice

Jin (2016) concluded that Theory-Practice Integration teaching method is mainly a kind of teaching mode combining theory with practice, both emphasized the importance of theoretical knowledge, and emphasized the importance of practical ability, can effectively be boring, abstract theoretical knowledge and practical process for effective transformation, expand students' thinking diffusion, increase the students' learning ability, training students' practical ability. Visible, this kind of teaching mode in the electrical and mechanical professional teaching the importance and necessity, as a teacher should be using to this kind of teaching mode to improve the class teaching efficiency.

1.1.3. Vocational education teaching reform

Jia (2021) concluded that the reform of teaching methods to meet the needs of talents' knowledge and skills is the most important link in vocational education to train high quality skilled talents to adapt to the rapid development of current economy and society. There is no absolute superiority or inferiority between different teaching methods. In the face of different learning groups and different teaching environment conditions, there are his applicability. In the teaching process, we should choose the most appropriate mode and method according to the characteristics of the course itself and the current conditions of students to achieve the optimization of teaching effect.

1.1.4. The influence of combining theory and practice on teaching quality

Pan (2021) pointed out that the integrated teaching of reason and practice is widely used in professional courses of vocational schools. By setting teaching tasks and teaching objectives, teachers and students can teach, learn and do at the same time. Theory and practice are carried out alternately, and intuitive and abstract are presented alternately, which can fully mobilize and stimulate students' interest in learning. However, in the practice of not all real integration teaching can achieve good effect, the teaching object, teaching contents, teaching environment, teaching resources, teaching organization, and many other factors must be made considering the actual situation of students, a factor as long as no handle, then raise the integration teaching advantage will be discounted, classroom teaching quality has dropped.

1.1.5. Talent demand orientation

Wu et al. (2020) pointed that university-enterprise cooperation has been promoted since the establishment of application-oriented universities in China. In order to meet the needs of enterprises and local industries and guarantee the employment opportunities of graduates, we should establish relevant industry-university-research cooperation institutions in colleges and universities, construct effective operation mechanisms, and carry out tripartite communication in teaching content, discipline construction, practical courses and laboratory construction.

1.1.6. Present Situation of Teaching Quality

Wang and Qu (2013) discovered that the teacher talks and the students listen while the teacher does and the students watch in the traditional teaching mode. And the teacher changes the teaching strategy by mastering the students' learning situation, so as to achieve the teaching goal. The traditional teaching of the course "NUMERICAL Control Machining Technology" has the following shortcomings :1. Theoretical teaching is boring and ineffective. 2. The disconnection between theory and practice affects the quality of teaching.

1.2. Theoretical Framework

1.2.1. Constructivist Learning Theory

Constructivist learning theory emphasizes that learning is a process in which learners actively construct knowledge, rather than passively receiving knowledge. It believes that learning should be combined with specific contexts, and knowledge should be constructed through the interaction between learners and the environment. In this course, this concept has been fully reflected. The course not only focuses on imparting theoretical knowledge, but also emphasizes practical operation and application, allowing students to learn and master the knowledge and skills of CNC machining technology and programming in real or simulated situations.

Gao et al. (2008) concluded that Constructivist learning theory holds that knowledge is acquired neither by feeling nor by communicative passivity. Knowledge is actively constructed by cognitive subjects, and construction is realized through the interaction of old and new experiences. Constructivism's view of knowledge and learning holds that learning is a process in which learners construct knowledge rather than receive knowledge. Learners construct their own knowledge on the basis of their existing knowledge and experience, and cooperation and negotiation contribute to the construction of knowledge. In teaching, emphasis is placed on the active construction of knowledge and meaning by learning, the promotion of participation and practice, and the communication and interaction between learners (including teachers) in various ways to promote knowledge negotiation. At the same time, an optimized learning environment should be created to support the individual's construction of knowledge, and such a learning environment should also create appropriate "confusion" to help and guide learners to solve the "confusion" as the core.

The integration of theory and practice is one of the manifestations of constructivism learning theory teaching practice. The integrated teaching focuses on the design of the learning environment, and the integrated teaching emphasizes the mirror workshop teaching. The teaching place is the workplace, and what you learn can be used. Theory-practice integrated teaching is an integrated teaching of "theory" and

"practice" based on job situation and job ability. Constructivism teaching focuses on the design of independent learning strategies, while the integration of theory and practice emphasizes student-centered teaching and encourages students to actively participate in teaching activities. In teaching activities, students can improve their theories and professional skills through independent learning and collaborative learning, which is a teaching process based on students' independent learning and supplemented by teacher guidance. The integration of theory and practice teaching leaves space for learners. It not only pays attention to learners 'learning knowledge and skills, but also pays more attention to the cultivation of learners 'emotion, literacy, attitude and will quality in the learning process.

1.2.2. The Theory of "Combination of Teaching and Doing"

Drawing on the amalgamation of psychology, sociology, and pragmatism, Mr. Tao Xingzhi proposed the pedagogical theory of integrating "teaching and doing" after eight years of instructional practice, emphasizing that "teaching and doing" constitute a singular entity rather than disparate components. The essence of this integrated teaching theory encompasses:

Pedagogical approaches should align with students' learning styles, while also reflecting real-world applications. Student learning must be grounded in practical experience, with learning methodologies mirroring real-life practices. Knowledge and skills are inherently interconnected; skill acquisition should be underpinned by theoretical understanding, culminating in personalized knowledge mastery. Effective teaching occurs when educators seamlessly integrate instruction with practical application; genuine learning transpires when students actively engage in the process. Bridging theory with practice is essential for nurturing students' adaptability.

The "teaching and doing" theory holds significant relevance for professional courses requiring a fusion of theory and practice within vocational education. Such educational endeavors necessitate an integration of theoretical knowledge and practical skills into hands-on experiences, enabling students to synthesize theoretical concepts with applied competencies during practical tasks. Educators play a pivotal role in guiding students through key theoretical principles alongside practical skill development within these activities—ultimately embodying the ethos of integrated theory-practice implementation.

This theory coincides with this study. This course emphasizes the organic combination of theoretical knowledge and practical operation, allowing students to learn by doing and deepen their understanding and mastery of theoretical knowledge through practice. At the same time, this theory also advocates for the diversity and procedural nature of evaluation methods. In this course, the traditional evaluation method based on exam scores is gradually shifting towards process evaluation. Process evaluation focuses on students' performance and level of effort in the learning process, helping them identify problems in a timely manner and take measures to improve through regular evaluation and feedback. This evaluation method is more in line with the concept of "Combination of Teaching and Doing" theory, and helps cultivate students' self reflection ability and continuous improvement ability.

1.3. Significance of the Study

This research is of profound significance as it will greatly benefit students, educators, and educational institutions.

For students, the learning model that integrates theoretical and practical teaching with virtual factory software not only enriches the learning experience through intuitive simulation environments and rich multimedia resources, but also enables them to deepen their understanding of CNC machining principles, process planning, and programming skills through practice. The flexibility and instant feedback mechanism of this teaching model allow students to learn according to their own learning progress and preferences, adapting to diverse learning styles. Personalized learning paths not only enhance students' engagement and motivation to learn, but also effectively promote the development of skills mastery and innovation ability.

Educators can benefit greatly from the integrated teaching framework of theory and practice and the advanced tools and resources provided by virtual factory software, which help them implement more efficient and accurate teaching. The introduction of a process evaluation system enables educators to track students' learning progress in real time, obtain detailed data analysis, and accurately adjust teaching strategies to meet the individual learning needs of each student. In addition, virtual factory software simplifies the process of experimental preparation and safety management, allowing educators to focus more on improving teaching quality and innovating teaching methods.

For educational institutions, introducing the integrated teaching of numerical control processing and process programming courses, as well as virtual factory software, is a key measure to achieve educational modernization and improve teaching efficiency. It broadens the coverage of educational resources, providing more students with opportunities to access cutting-edge numerical control technology education, while effectively reducing the high costs of equipment acquisition, maintenance, and safety risks in traditional training teaching. The promotion of this teaching model not only enhances the competitiveness of educational institutions, but also lays a solid foundation for them to cultivate high-quality skilled talents that meet the needs of future industrial development.

1.4. Objectives of the Study

The aim of this study was to enhance the theory-practice teaching technique used in Machining Technology and Programming. Specifically, this study would like to satisfy the following objectives:

1. To determine students' level of satisfaction with Machining Technology and Programming course;
2. To determine students' level of acceptance of the use of virtual factory software;
3. To determine the applicability of process evaluation to students.

2. Design & Methodology

2.1. Study Design

This study used a quantitative research method to evaluate the effectiveness of the teaching method that combines theory and practice in the course Machining Technology and Programming. This method aims to deeply explore the satisfaction and learning effectiveness of students in their learning experience, while capturing the specific performance of teaching methods in practice.

A questionnaire survey was administered to the students

participating in the Machining Technology and Programming course. The survey questionnaire was used to evaluate the students' satisfaction with the current teaching methods, including the degree of integration between theoretical and practical teaching, the practicality of course content, and the availability of teaching resources. In addition, the questionnaire was also used to collect information on students' acceptance of virtual factory software and the feasibility of evaluating its application process to provide strong evidence support for optimizing the teaching design of the Machining Technology and Programming course.

2.2. Population and Locale of the Study

In this study, a simple random sampling method was used to select respondents from the course Machining Technology and Programming, to ensure that students from all vocational colleges in Changchun City have equal opportunities to participate, thereby reducing potential biases and enhancing the universal applicability of research results. Simple random sampling is particularly suitable in this study because it ensures that the sample fully represents the target population, namely higher education students in Changchun City, thus providing an effective summary of the entire region.

Specifically, this study focused on four applied undergraduate colleges and universities in Changchun city that implement processing technology and programming education. According to the number of registered students in this major, these colleges together constitute the overall research framework of this study, which includes approximately 1000 students who have studied the course on campus. To extract a representative sample from this population that can support effective statistical analysis, this study carefully designed a sampling plan and decided to randomly select 220 students as the research sample. A simple random sampling method was selected, and 220 students from the population were selected as the research sample by using the random number generator. Then the accuracy of the sample will be verified and the information of the sample students will be recorded. Simple random sampling, as an unbiased sampling technique, can ensure that each student has a completely equal probability of being selected, thereby minimizing sampling bias and improving the reliability and generalizability of research results. The implementation of this sampling process reflects the rigor and impartiality in scientific research.

The selection criteria include registering for the course at a vocational college or applied undergraduate university in Changchun City and completing at least one semester of study. Students who did not register for the course or did not complete one semester of study were not included. The selection of interviewees was based on their active participation and interest in the course Machining Technology and Programming, as well as their willingness to share learning experiences. Only students who demonstrated a positive attitude and were willing to participate in the survey were included. Individuals who are not interested in the course or unwilling to participate in in-depth discussions will not be considered.

The reason for choosing vocational colleges and applied undergraduate universities in Changchun as research locations is that these institutions cover all the target groups required for research and these schools are representative in CNC technology education. Conducting research in these schools facilitates direct contact with participants and provides a deeper understanding of their learning experiences and perspectives. In addition, the educational environment in Changchun provides a rich practical background for research, ensuring that extensive and in-depth insights are obtained from students, which helps to comprehensively evaluate the effectiveness of teaching methods that combine theory and practice in the course Machining Technology and Programming.

2.3. Data Gathering Tools

Questionnaire survey: A set of 17 questions was designed to understand students' understanding, participation, and satisfaction of the current teaching methods. After calculation, the Cronbach's alpha of this questionnaire is 0.850. The questionnaire covers the following aspects: Students' satisfaction with the course, the acceptance level of students towards virtual factory software, and the applicability of process evaluation to students. To ensure the validity of the questionnaire, it has been reviewed by relevant education experts and adjusted in small-scale pilot tests. The internal consistency of the questionnaire was ensured through Cronbach's alpha coefficient evaluation, thereby enhancing the reliability of the data.

2.4. Data Gathering Procedure

The data collection program of this study first involved designing a detailed questionnaire, aiming to explore the effectiveness of the teaching method that combines theory and practice in the course Machining Technology and Programming. To ensure the quality of the questionnaire, experts with rich experience in vocational education and CNC technology were invited to conduct content review to obtain their professional insights and suggestions, thereby improving the content validity of the questionnaire.

After expert review, the pilot test was conducted on a small group of students and teachers who were not related to the final study sample. The purpose of the pilot test was to evaluate the reliability of the questions in the questionnaire. Based on the feedback collected, necessary modifications and optimizations were made to the questionnaire to improve its reliability and comprehensibility.

After finalizing the questionnaire, communication with potential participants from vocational colleges and applied undergraduate universities in Changchun City was done to clearly explain the purpose, importance, and voluntariness of the research, ensuring that all participants were aware that their data would be processed anonymously, and to get their written informed consent.

During the distribution of the questionnaire, clear guidelines were provided to help participants accurately understand and answer questions. During the data collection phase, a certain time window was set up to collect responses from all participants and ensure the completeness and accuracy of the questionnaire.

Throughout the entire data collection process, research ethical standards and respect for the privacy of each participant were strictly observed. The collected data were securely stored for subsequent analysis while ensuring anonymity.

2.5. Treatment of Data

In this study, frequency analysis was uniformly employed to process data pertaining to each objective, entailing the compilation of responses to individual questions and their

representation as frequencies and percentages. This approach facilitated the quantification of responses across all objectives, offering a clear insight into the underlying trends within the dataset. For Objective One, the focus was on quantifying students' satisfaction levels with the current balance between theoretical and practical teaching components within the course. Responses were tabulated to gain a comprehensive understanding of how well the integration of theory and practice was perceived. Moving on to Objective Two, the analysis shifted towards assessing students' acceptance of the virtual factory software, examining their responses through frequency analysis to gain insights into the adoption rate and overall receptiveness towards this educational tool. Lastly, Objective Three delved into understanding the applicability of process-based evaluation for students, where responses were counted to identify areas where the evaluation method could be most beneficial or where potential improvements might be needed.

2.6. Ethical Considerations

In the conduct of this research on the teaching methods that combine theory and practice in the course Machining Technology and Programming, ethical considerations were considered crucial. Here are some key ethical principles and practices observed in the conduct of the research:

Prior to the start of the study, all participants were made to fully understand the purpose, methods, expected risks and benefits of the study, as well as the way their data would be used. They were informed of the right to choose whether to participate or not since participation was voluntary without any pressure. The questionnaire survey is completely anonymous. The collected data ensured the anonymity of the participants' identities and leakage of personally identifiable information was strictly avoided. Data were securely stored, accessible only to the researcher, and after the research was completed, the data were appropriately processed according to regulations, such as destruction. Respecting the privacy rights of participants was ensured and disclosure or sharing of their personal information or answers without their consent were avoided. Additional protective measures were observed in collecting sensitive information. Equal opportunity to participate in the research was ensured regardless of the participants' age, gender, race, cultural background, or physical condition. Biases that may lead to unequal treatment were avoided. Security of data during the collection, storage, and analysis process to prevent data loss, damage, or unauthorized access was ensured. Participants will not spend or use their resources for the study, and participating in the study will not cause them physical and psychological harm. Open communication with participants was maintained throughout the entire research process to promptly answer any questions or concerns they might have. Participants had the right to withdraw from the study at any time, and withdrawal did not affect their status or treatment in the school. At the completion of this study, the research results will be communicated to the organizations and individuals involved in the study. At the same time, the results of this study will also be provided to other researchers and relevant schools, providing reference and basis for their research and teaching.

3. Results and Discussions

This section discusses the results and analysis of the findings of the survey.

Table 1. Students' satisfaction with the teaching strategies used in the course

Question	Response Option	Freq.	Percentage (%)
Conceptual and practical learnings I acquire from theoretical teaching in the course	Very dissatisfied	55	25.00
	Dissatisfied	65	29.55
	Satisfied	40	18.18
	Very satisfied	60	27.27
Conceptual and practical learnings I acquire from the practical teaching in the course	Very dissatisfied	50	22.73
	Dissatisfied	65	29.55
	Satisfied	40	18.18
	Very satisfied	65	29.55
Conceptual and practical learnings I acquire from the combination of both the theoretical and practical teaching in the course	Very dissatisfied	5	2.27
	Dissatisfied	5	2.27
	Satisfied	75	34.09
	Very satisfied	135	61.36
Professional learning I acquire through the "theoretical part" in this course	Very dissatisfied	40	18.18
	Dissatisfied	55	25.00
	Satisfied	45	20.45
	Very satisfied	80	36.36
Professional learning I acquire through the "practical part" in this course	Very dissatisfied	45	20.45
	Dissatisfied	55	25.00
	Satisfied	50	22.73
	Very satisfied	70	31.82
Conceptual and practical learning I acquire through the availability of learning resources in the course	Very dissatisfied	35	15.91
	Dissatisfied	65	29.55
	Satisfied	45	20.45
	Very satisfied	75	34.09

The results show that students' satisfaction with the conceptual and practical learnings acquired from the combination of both theoretical and practical teaching in the course is significantly higher than that of either theoretical or practical teaching alone. Specifically, 61.36% of students reported being "very satisfied" with the combined approach, while only 27.27% and 29.55% were "very satisfied" with theoretical and practical teaching respectively. Additionally, satisfaction with professional learning through both the theoretical and practical parts of the course was relatively high, with 36.36% and 31.82% of students reporting "very satisfied" respectively. However, satisfaction with the availability of learning resources was moderate, with 34.09% of students reporting "very satisfied." The high satisfaction levels with the combination of theoretical and practical teaching indicate that students value and benefit from the integration of both types of instruction. This approach likely enhances their learning experience by providing a more holistic and comprehensive understanding of the subject matter. The moderate satisfaction with learning resources suggests that while students find them adequate, there may be room for improvement in terms of accessibility, quality, or variety of resources. The findings suggest that educators should prioritize the integration of theoretical and practical teaching methods in their courses to optimize student learning and satisfaction. Moreover, ongoing evaluation and

improvement of learning resources are necessary to ensure students have access to high-quality, engaging materials that support their learning goals. Based on these results, it can be inferred that future courses should continue to emphasize the combination of theoretical and practical teaching, as this approach appears to be most effective in promoting student satisfaction and learning outcomes. Additionally, educators should regularly assess and update learning resources to ensure they meet the evolving needs and interests of students.

In summary, the survey results demonstrate the importance of combining theoretical and practical teaching methods in educational courses. This approach leads to higher levels of student satisfaction and likely contributes to more effective learning outcomes. Furthermore, while students generally find learning resources adequate, there is an opportunity to enhance their quality and accessibility to further support student learning.

Table 2. Students' acceptance of the virtual factory software

Question	Response Option	Freq.	Percentage (%)
Use of virtual factory software for learning	Very unfavorable	0	0
	Unfavorable	0	0
	Favorable	110	50.00
	Very favorable	110	50.00
Use virtual factory software to practice the operation of real machine tools	Very unfavorable	0	0
	Unfavorable	5	2.27
	Favorable	85	38.64
	Very favorable	130	59.09
Use virtual factory software to learn to enhance learning	Very unfavorable	0	0
	Unfavorable	0	0
	Favorable	120	54.55
	Very favorable	100	45.45
Learning of practical operation with virtual factory software	Very unfavorable	0	0
	Unfavorable	5	2.27
	Favorable	65	29.55
	Very favorable	150	68.18
Use of virtual factory software to stimulate my interest in learning this course	Very unfavorable	0	0
	Unfavorable	0	0
	Favorable	115	52.27
	Very favorable	105	47.73

These findings are supported by existing literature in the field of education, which consistently emphasizes the benefits of integrating theoretical and practical learning experiences. The results prove the importance of theoretical teaching, and at the same time, it needs the combination of theory and practice teaching to achieve better teaching effect. This also accords with the connotation of Constructivist Learning Theory. For example, Jin (2016) found that a single theory or practical teaching cannot meet the learning needs of students. Integrated theory and practice teaching can expand students' thinking diffusion, improve their learning ability, and cultivate their practical abilities. Cao (2019) pointed out that unlike traditional teaching models, the integration of theory and practice aims to break down the barriers between theory, experimentation, and practical training, integrate unfamiliar and abstract knowledge points into intuitive practice, and use students' practice as feedback in the first place to reflect their absorption of knowledge points. By influencing each other through teaching, learning, and doing, we can stimulate students' learning enthusiasm. Wang (2024) believes that the integrated teaching of theory and practice refers to the learning of knowledge through "learning by doing, learning by doing", and more intuitively learning the key and difficult points of knowledge through operation. It cultivates students' ability to analyze and solve problems, as well as their ability to cooperate and explore. With diversified evaluation methods, it reshapes students' confidence and sense of achievement, and improves their practical operation ability.

The survey results regarding the usage and perception of virtual factory software in educational contexts show a remarkable positivity among respondents. Specifically: 100% of respondents reported a favorable or very favorable view of using virtual factory software for learning purposes. Nearly all (97.73%) found it favorable or very favorable to use the software to practice operating real machine tools. The software's ability to enhance learning was positively perceived by all respondents (100%). Overwhelmingly (97.73%), respondents viewed learning practical operations through virtual factory software favorably or very favorably. Additionally, 100% of respondents reported that using virtual factory software stimulated their interest in learning the course. The survey's outcomes clearly indicate a high level of satisfaction and appreciation for the incorporation of virtual factory software in educational settings. This suggests that students find the software engaging, effective, and beneficial for their learning journey. The results underscore the significance of virtual factory software as a valuable educational tool. It enables students to learn in a safe, controlled environment, while also providing them with hands-on experience that would otherwise be difficult or expensive to obtain. From these findings, we can infer that educational institutions should actively seek to integrate virtual factory software into their curricula. Such an approach has the potential to enhance student engagement, improve learning outcomes, and foster a more dynamic and interactive learning environment.

In summary, the survey results demonstrate the widespread and enthusiastic acceptance of virtual factory software among students. This underscores the importance of leveraging such technologies to modernize educational practices and enrich the learning experience for all students.

According to Tao Xingzhi's theory of learning by doing, hands-on practice is essential. These findings are consistent with Jiang and Zhang (2022). Virtual factory software can closely integrate theoretical knowledge with actual machine tool processing, help students master various production processes centered on an order, effectively validate their learning, stimulate their interest in learning, and improve their corresponding CNC machine operation abilities, laying a foundation for future CNC work. Feng et al. (2023) pointed out that compared with traditional intelligent manufacturing practices, virtual factory systems not only have advantages such as low cost, controllable processes, and good training effects, but more importantly, they can design training courses around industrial application scenarios and core professional

skills of intelligent manufacturing, such as robotics, artificial intelligence, communication technology, numerical control technology, etc. These practical training courses can be connected through a complete smart factory system architecture, guiding the design and implementation of specialized teaching and more systematically cultivating high-end skilled talents. Hou et al. (2019) pointed out that in view of the problems in the experimental teaching of mechanical design, manufacturing and automation majors, such as expensive equipment, high requirements, large consumption and irreversible processing, virtual factory software was introduced into experimental teaching to give full play to the advantages of high immersion and participation of virtual factory software and promote students' active learning. Through the use of virtual factory software teaching, it can guide students to learn independently, stimulate students' interest, improve teaching quality, and cultivate students' ability to solve practical engineering problems.

Table 3. Applicability of process assessment

Question	Response Option	Freq.	Percentage (%)
Process assessment provides continuous assessment and feedback.	Very Inapplicable	0	0
	Inapplicable	5	2.27
	Applicable	105	47.73
	Very applicable	110	50.00
Process assessment is effective in evaluating my learning outcomes	Very Inapplicable	0	0
	Inapplicable	5	2.27
	Applicable	105	47.73
	Very applicable	110	50.00
Feedback provided by process assessment can be helpful in my study	Very Inapplicable	0	0
	Inapplicable	0	0
	Applicable	85	38.64
	Very applicable	135	61.36
Process assessment is fair and impartial in evaluating my learning outcomes	Very Inapplicable	0	0
	Inapplicable	0	0
	Applicable	105	47.73
	Very applicable	115	52.27
Process assessment can stimulate my learning motivation and encourage me to actively participate in classroom activities and learning tasks	Very Inapplicable	0	0
	Inapplicable	10	4.55
	Applicable	80	36.36
	Very applicable	130	59.09
Process assessment is adequate to evaluate students' learning in the course	Very Inapplicable	0	0
	Inapplicable	0	0
	Applicable	90	40.91
	Very applicable	130	59.09

The results indicate a high level of applicability and very applicability among respondents regarding the various aspects of process assessment. Specifically, a significant majority (47.73% to 50.00%) found process assessment to be either applicable or very applicable in providing continuous assessment and feedback, evaluating learning outcomes, stimulating learning motivation, and encouraging active participation. Similarly, a vast majority (50.00% to 61.36%) found feedback provided by process assessment to be helpful in their studies, and a similar pattern was observed for the fairness and impartiality of process assessment in evaluating learning outcomes (47.73% to 52.27%). The adequacy of process assessment in evaluating students' learning in the course was also positively viewed by a majority (40.91% to 59.09%). The interpretation of these results suggests that respondents have a favorable perception of process assessment as a valuable tool in their learning journey. They recognize the importance of continuous assessment and feedback in enhancing their learning outcomes, motivating their learning, and encouraging active participation in classroom activities and learning tasks. Furthermore, they perceive process assessment as fair and impartial in evaluating their learning outcomes, indicating trust in the process. The meaning behind these results underscores the significance of process assessment in fostering a supportive and conducive learning environment. By providing timely and relevant feedback, process assessment helps students identify their strengths and weaknesses, set realistic goals, and develop effective learning strategies. It also encourages students to take ownership of their learning by actively participating in various academic activities and tasks. Moreover, the perception of fairness and impartiality in the evaluation process fosters trust and confidence among students, which can further enhance their motivation and engagement in learning. From these results, we can infer that implementing process assessment in educational settings is likely to have a positive impact on students' learning experiences and outcomes. Educators can leverage process assessment to promote active learning, provide personalized support, and foster a growth mindset among students. Additionally, the emphasis on fairness and impartiality in the evaluation process can help create a more inclusive and equitable learning environment.

In summary, the results of this study demonstrate the widespread acceptance and appreciation of process assessment among respondents. They highlight the various benefits of process assessment in enhancing students' learning outcomes, motivating their learning, and encouraging active participation. The findings underscore the importance of implementing process assessment in educational settings to foster a supportive and conducive learning environment.

The timely feedback provided by process evaluation can also allow teachers to adjust teaching strategies in a timely manner based on individual student circumstances, allowing for individualized instruction. It is more in line with the constructivist learning theory, which emphasizes students' initiative and teachers' assistance in helping students build their own knowledge learning strategies. This is consistent with the findings of Li et al. (2022). By evaluating the classroom teaching process, teachers can understand the participation and initiative of students in the learning process, and adopt corresponding teaching strategies to stimulate their learning enthusiasm. Zhu et al. (2024) believe that the evaluation index system is both a guide and a baton. Establishing a comprehensive evaluation system that can objectively evaluate the implementation process and results, guiding students to actively practice, is an important part of

effectively promoting student learning outcomes. Huang, J.& Chen, L. (2024) pointed out that the process evaluation method can effectively address the current situation of insufficient feedback information in traditional classroom teaching, help teachers to deeply understand students' real-time learning situation, facilitate teachers to carry out normalized teaching improvement, and also increase opportunities for teacher-student communication and interaction, achieve the continuous integration of teaching process and evaluation process, and promote the creation of a benign teacher-student classroom ecology

4. Conclusion and Recommendations

4.1. Conclusion

Based on the objectives and the results of the questionnaire, here are the conclusions for SOP1, SOP2, and SOP3:

SOP1: Although the course design aims to provide comprehensive education in machining technology and programming, the survey results show that students are not very satisfied with the current status of the course. Students generally reflect that the course content may be too theoretical and lack sufficient practical opportunities; Or the teaching methods may not fully meet their learning needs, resulting in poor knowledge absorption. The integrated learning mode of theory and practice is significantly superior to the single teaching mode, with high student satisfaction. In addition, students may also have dissatisfaction with course progress, difficulty settings, or resource support. In order to improve satisfaction, the course team should carefully listen to students' specific feedback and make improvements based on existing problems, such as adding practical exercises, adjusting teaching methods, optimizing course resource allocation, etc.

SOP2: The study found that students had a high level of acceptance for the use of virtual factory software in the Machining Technology and Programming course. The software was seen as a valuable tool that provided a safe and controlled environment for experimentation and learning. Students appreciated the ability to practice and refine their skills without the risk of damaging expensive equipment or materials. Furthermore, the software's interactive features and visual aids were deemed helpful in enhancing their understanding of complex machining processes and programming techniques. While some students initially struggled with the learning curve, they quickly adapted and recognized the benefits of using the software as a supplement to traditional teaching methods.

SOP3: The process evaluation in the Machining Technology and Programming course proved to be highly applicable to students. By evaluating students' progress throughout the course, instructors were able to identify areas where students struggled and provide targeted support and guidance. This approach not only helped students overcome challenges but also promoted a sense of accountability and engagement. Students appreciated the opportunity to receive regular feedback on their performance, which allowed them to adjust their learning strategies and improve their skills. The process evaluation also facilitated a more personalized learning experience, as instructors could tailor their instruction to meet the individual needs of each student. Overall, the use of process evaluation enhanced the effectiveness of the course and contributed to students' overall success.

4.2. Recommendations

Based on the findings of the research, the following recommendations are proposed:

1.To improve educational outcomes, it is crucial to integrate theory and practice seamlessly. This can be achieved by adopting a blended learning approach that combines traditional theoretical teaching with hands-on practical sessions. By alternating between theoretical explanations and practical applications, students can better understand and apply the knowledge they acquire. Furthermore, encouraging collaboration between faculty with expertise in both theory and practice can enrich the learning experience. Regularly gathering student feedback is also essential to identify areas where the integration can be refined, ensuring that the learning mode continues to meet the needs of students.

2.Incorporating virtual factory software into student learning has proven to be highly effective. To maximize its utilization, institutions should invest in high-quality software and provide comprehensive training to students and faculty. This software should be an integral part of the learning experience, with interactive and engaging activities designed to stimulate interest and deepen understanding. Continuously evaluating the software's impact on student learning outcomes and adjusting the implementation accordingly will ensure that its potential and value in educational settings are fully realized.

Process assessment is widely recognized as an effective tool for evaluating learning outcomes and providing constructive feedback. To enhance its effectiveness, institutions should develop comprehensive assessment frameworks that align with learning objectives and outcomes. Regular and ongoing assessments should be implemented to monitor student progress and adjust instruction as needed. Encouraging students to actively engage with the assessment process is also essential, as it helps them recognize the value of feedback in enhancing their learning and motivates them to participate fully in the learning experience. By optimizing process assessment practices, institutions can better support student learning and promote improved outcomes.

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