Article

Research on Teaching Reform of Numerical Control Programming and Machining in Higher Vocational Colleges Based on the 1+X Certificate System

Jianhua Dai [1] and Tao Wang [1,*]

[1] Intelligent Manufacturing College Fujian Polytechnic of Information Technology, Fuzhou, Fujian, 350003, China
* Correspondence: Tao Wang, Intelligent Manufacturing College Fujian Polytechnic of Information Technology, Fuzhou, Fujian, 350003, China

Abstract: In response to prevalent issues in the Numerical Control Programming and Machining course in higher vocational colleges, such as the disconnection between theory and practice, monotonous teaching methods, and an inadequate evaluation system, this study analyzes the significant role of the "1+X Certificate" system in vocational education. It proposes reform strategies aimed at optimizing the curriculum system, innovating teaching approaches, and refining the evaluation mechanism. The findings indicate that teaching reforms driven by the "1+X Certificate" system can effectively address the dilemmas of traditional instruction, thereby providing a valuable reference for pedagogical innovation in the field of Numerical Control machining within higher vocational education.

Keywords: 1+X certificate system; numerical control programming and machining; higher vocational colleges; teaching reform

Published: 27 January 2026

1. Introduction

Amidst the global wave of manufacturing transformation and upgrading, Numerical Control (NC) machining technology, as a crucial pillar of modern manufacturing, is extensively applied in key sectors such as automotive, aerospace, and electronics. With the deepening advancement of concepts like Smart Manufacturing and Industry 4.0, the manufacturing industry's demand for NC machining professionals has escalated in both competency and quantity. Beyond solid programming and operational skills, talents are now required to possess innovative thinking, teamwork capabilities, and the learning agility to quickly master new technologies, enabling them to cope with ever-evolving production environments and technical challenges.

In response to the urgent demand for NC professionals, China initiated a pilot of the "1+X" Certificate System in 2019. The core objective of this system is to promote the organic integration of academic diplomas and vocational skill level certificates. It encourages students to actively acquire multiple vocational skill certificates alongside their academic credentials, thereby enhancing their employability and broadening career pathways [1]. Emphasizing" curriculum-certificate integration" and "diploma-certificate linkage," the system focuses on practical skill cultivation. It aims to address the long-standing disconnection between theory and practice in traditional vocational education, enabling students to better meet the actual production needs of enterprises [2].

In higher vocational colleges, within majors such as Mechanical Manufacturing & Automation and Mold Design & Manufacturing, the NC Programming and Machining course is a core foundational subject pivotal to cultivating NC machining talents. However, current teaching of this course exhibits several notable shortcomings: the course content is inadequately aligned with vocational skill level standards, failing to fully reflect the skill-oriented requirements of the "X" certificates; teaching methods remain predominantly traditional lecture-based, with relatively weak practical components, resulting in deficiencies in students' hands-on operational and problem-solving abilities; assessment overly emphasizes theoretical knowledge, lacking a comprehensive evaluation of practical skills and professional competency, thus failing to accurately reflect students' overall competency levels [3]. These issues not only constrain students' future career development but also hinder the overall improvement of course teaching quality. Consequently, guided by the "1+X" Certificate System, reforming the teaching of the NC Programming and Machining course in higher vocational education is both highly necessary and urgent.

2. Analysis of the Current Teaching Status of the NC Programming and Machining Course in Higher Vocational Education

2.1. Course Orientation and Objectives

The NC Programming and Machining course in higher vocational education is closely aligned with the actual job requirements in the NC machining field. It aims to cultivate students' solid programming and practical operation abilities, enabling them to skillfully operate NC equipment and complete machining tasks for various parts. In terms of knowledge, students are required to master the basic instructions and code formats of NC programming, understand the fundamental principles and methods of machining processes, and become familiar with the structure, working principles, and operational interface of NC machine tools. Regarding skills, students should be able to independently complete NC programming based on part drawings, proficiently operate machine tools for machining, and use measuring tools to inspect part accuracy. Additionally, they need to preliminarily acquire the ability to debug, maintain, and troubleshoot common issues with NC equipment to ensure the smooth running of the machining process. In the aspect of professional competency, the course emphasizes guiding students to develop safety awareness, a quality mindset, teamwork, and innovative thinking. This helps students better adapt to the complex and changing demands of the future workplace, fostering their growth into responsible NC technical professionals with sound professional competency [4].

2.2. Problems in the Traditional Teaching Mode

2.2.1. Disconnection Between Theory and Practice

In the traditional teaching of the NC Programming and Machining course, theoretical instruction and practical training are often segregated. Theoretical components are primarily delivered in the classroom, where teachers explain programming principles, process methods, and related knowledge using blackboards, PowerPoint presentations, etc. Practical sessions, however, are scheduled in training workshops where students operate NC machine tools to complete exercises. This spatio-temporal separation often leads to a temporal disconnect between theoretical learning and hands-on operation. After learning theoretical concepts, students frequently cannot proceed to practical application promptly, having to wait for the scheduled workshop session. Consequently, students find it difficult to effectively transfer the learned knowledge into practical operational skills.

2.2.2. Monotonous Teaching Methods

In the traditional NC Programming and Machining course, teaching methods remain predominantly teacher-centered lecturing. In the classroom, teachers often hold a dominant position, explaining relevant knowledge and skills step-by-step according to the textbook. This model overly emphasizes the one-way transmission of knowledge and fails to adequately acknowledge students' central role and learning autonomy. Students are largely placed in a passive receiver mode during the teaching process, lacking space for independent thinking and active exploration. This, to some extent, dampens their learning interest and motivation.

2.2.3. Inadequate Assessment and Evaluation Methods

The assessment method for the traditional NC Programming and Machining course still relies heavily on theoretical examinations, focusing primarily on testing students' memorization and comprehension of related theoretical knowledge. Such an evaluation system struggles to provide a comprehensive and authentic reflection of students' practical abilities in programming and machining. In actual work, NC programming and machining professionals not only require a solid theoretical foundation but, more importantly, depend on proficient practical operational skills and rich on-site experience. They must be capable of making quick judgments and taking appropriate, effective corrective actions based on real-time machining conditions.

3. The Significant Role of the "1+X" Certificate System in Vocational Education

3.1. Improving the Vocational Education and Training System

The systematic implementation of the "1+X" Certificate System has effectively steered vocational colleges towards a dual-track educational approach that integrates education with training, thereby refining the vocational education and training ecosystem. Traditional vocational education models often prioritized academic credentialing, with relatively insufficient investment in students' vocational skill training, leading to a gap between graduates' practical abilities and actual job requirements. The introduction of the "1+X" system has disrupted this singular educational paradigm, elevating the importance of vocational skill training. It encourages institutions to actively develop diverse and targeted vocational training programs, thereby expanding students' learning pathways and developmental opportunities.

Vocational colleges can flexibly design various vocational skill level certificate training courses based on market demands and student career aspirations. These courses are closely aligned with actual enterprise production, enabling students to engage with the latest industry technologies and processes, thus effectively enhancing their practical operation and problem-solving skills. Concurrently, the "1+X" system has mobilized social resources to participate in vocational education. Enterprises and industry organizations, leveraging their technical, equipment, and talent advantages, provide institutions with abundant teaching resources and practical platforms. This further strengthens the vocational training system and fosters a more open and collaborative educational landscape.

3.2. Deepening the Reform of Talent Cultivation Models

The implementation of the "1+X" Certificate System has catalyzed a shift in talent cultivation from a singular focus on academic education towards a composite growth model, injecting new momentum into the reform of vocational talent development. Traditional vocational models often overemphasized theoretical knowledge transmission while underdeveloping students' practical skills and professional competency, resulting in graduates struggling to quickly adapt to the practical demands of enterprise positions [5]. In contrast, the "1+X" system mandates that vocational colleges restructure their talent cultivation plans and curriculum systems, guided by vocational skill level standards. This achieves an organic integration of academic education and skill training, truly realizing "curriculum-certificate integration" and "diploma-certificate linkage." Specifically in the field of NC programming and machining, the system facilitates the deep integration of relevant vocational skill level standards into the curriculum. Using authentic enterprise production tasks as the vehicle, it constructs teaching content characterized by "post-certificate-course integration." It innovatively adopts a layered teaching model of "theory

+ simulation +hands-on operation" and establishes a diversified evaluation system covering knowledge, skills, and professional competency. These measures address the theory-practice disconnect prevalent in traditional courses while achieving effective alignment between academic education and vocational training. Consequently, talent cultivation shifts from a "knowledge-based" to a "competency-based" orientation, thereby more precisely meeting the NC industry's demand for composite skilled talents proficient in programming, machining, and process optimization.

3.3. Enhancing Student Employability

The "1+X" Certificate System demonstrates a significant effect on improving student employability. In today's competitive job market, corporate expectations for candidates are increasingly stringent, focusing not only on solid professional knowledge but also on robust practical experience and vocational skills. By obtaining both an academic diploma and multiple vocational skill level certificates, students can present a more comprehensive profile of their integrated capabilities and professional competency to potential employers, thereby securing a more advantageous position in the job search. For positions related to NC programming and machining, graduates holding corresponding vocational skill level certificates are generally more favored by enterprises than those with only an academic diploma. These certificates serve as valid proof of students' skill proficiency and practical competence, indicating their ability to adapt more quickly to job requirements and deliver tangible value to employers. Furthermore, the "1+X" system broadens students' employment options. Based on their interests and career plans, they can pursue vocational skill level certificates in different specializations, thereby accessing more career pathways and enhancing the flexibility and adaptability of their professional development.

4. Teaching Reform Strategies for NC Programming and Machining in Higher Vocational Education Based on the "1+X" Certificate System

4.1. Optimizing the Curriculum System

The current implementation of the "1+X" Certificate System focuses on cultivating students' comprehensive vocational competencies, steering the objectives of the NC Programming and Machining course towards producing composite NC professionals. The system's standards clearly define the knowledge, skills, and competency required for personnel at different levels. For instance, the elementary certificate requires students to possess abilities in basic programming commands, simple part machining processes, and fundamental machine tool operation. The intermediate certificate imposes higher demands, such as programming for complex parts, multi-axis machining, and precision control. The advanced certificate emphasizes comprehensive capabilities, including the application of smart manufacturing technologies, process optimization, and solving complex production problems [6].

Within this framework, the "1+X" system systematically integrates the core requirements of vocational skill level standards into the curriculum, constructing a layered teaching content structure comprising "Foundation Modules + Skill Modules + Certificate Articulation Modules." By streamlining theoretical redundancies, strengthening hands-on training based on authentic enterprise tasks, and integrating resources such as simulation software and intelligent training equipment, the course achieves effective alignment between vocational standards and teaching content, production processes and teaching processes, as well as academic diplomas and skill certificates. Consequently, the entire curriculum system becomes more targeted, practical, and occupationally adaptive, laying a solid curricular foundation for cultivating composite NC skilled talents that meet industry needs.

4.2. Innovating Teaching Methods and Tools

4.2.1. Application of Project-Based Teaching Method

The project-based teaching method, guided by "1+X" certificate assessment projects, effectively enhances students' learning motivation and initiative, promoting the holistic development of their comprehensive abilities. During project implementation, the teacher primarily acts as a facilitator, providing necessary technical support and guidance. Students, through research, analysis, discussion, and practical operation, autonomously solve problems encountered in project progression, thereby honing their self-directed learning and problem-solving skills. The specific task flow includes: during process analysis, students must rationally plan the machining process, select tools, cutting parameters, and machining methods based on part drawings and technical requirements; in the programming phase, they apply their knowledge to write NC programs based on the process analysis results; during machining execution, they operate NC machine tools, import the programs, and complete part machining; finally, in the precision inspection stage, they use measuring tools to inspect the finished product and determine if it meets design specifications.

Upon project completion, through a dedicated outcome presentation and evaluation platform, students are required not only to present the final outcome but also to systematically review the practical process and reflections. This exercise trains their language organization and communication skills, fostering a two-way enhancement of knowledge output and expressive ability [7]. The evaluation session adopts a teacher-led, student-participatory approach, conducting comprehensive assessment across multiple dimensions: it focuses both on the achievement of project objectives and the practical effectiveness of technical solutions, as well as on teamwork efficiency and problem-solving. The evaluation process emphasizes positive guidance: first affirming students' innovative points and strengths, then objectively analyzing shortcomings in execution, and finally proposing actionable improvement suggestions based on practical contexts. This forms a closed-loop evaluation, providing a clear pathway for students' subsequent competency enhancement and promoting their continuous progress in practice. Through project-based teaching, students, in the process of completing authentic tasks, not only solidly master the knowledge and skills of NC programming and machining but also cultivate teamwork, innovation awareness, and professional competency, holistically improving their comprehensive abilities and laying a solid foundation for obtaining "1+X" certificates and their future career development.

4.2.2. Deepening Integrated Theory-Practice Teaching

Against the backdrop of the "1+X" Certificate System, integrated theory-practice teaching can effectively promote curriculum-certificate integration, enhance students' practical abilities, and achieve the organic fusion of theoretical instruction and practical training [8]. In specific implementation, teachers can flexibly arrange the sequence and duration of theory and practice based on the teaching content and students' actual situations, allowing students to understand theory through practice and conduct operations under theoretical guidance. For example, when explaining NC programming commands, the teacher can combine real machining cases to perform live demonstrations on an NC machine tool. By dynamically demonstrating the actual execution process of commands during machining, students can intuitively understand their functions and application logic, thereby breaking down the barrier between abstract theory and practical operation. Following the demonstration, opportunities for hands-on operation must be created for students. In the practice of independently completing the entire programming and machining workflow, students translate theoretical knowledge into concrete experience, truly mastering the application details of the commands and achieving the competency leap from "understanding" to "doing."

Simultaneously, institutions should strengthen the construction of training bases to provide robust hardware support for integrated theory-practice teaching. Training bases need to be equipped with advanced NC equipment, simulation software, and relevant teaching resources to meet students' diverse practical needs. Base construction can reference authentic enterprise production environments to create a workplace atmosphere, helping students adapt to work scenarios in advance during training and enhance professional competency. The training base can be divided into a production zone, a teaching zone, and a discussion zone: the production zone is equipped with devices such as NC lathes, milling machines, and machining centers for students to perform actual machining operations; the teaching zone is furnished with multimedia teaching equipment to facilitate theoretical explanations and case-based teaching; the discussion zone is used for group collaboration and project exchange, promoting collaboration and reflection.

4.3. Improving the Teaching Evaluation System

4.3.1. Constructing a Diversified Evaluation System

Under the "1+X" Certificate System, the evaluation system should cover multiple dimensions such as knowledge, skills, and professional competency, forming a comprehensive and diversified assessment mechanism. For knowledge evaluation, the focus extends beyond students' memorization and comprehension of theoretical knowledge to emphasize their ability for practical application and expansion of knowledge. Skill evaluation, based on the assessment standards of "1+X" certificates, designs practical projects of varying difficulty levels, conducting comprehensive assessments from aspects such as operational protocol, machining accuracy, and programming capability. Furthermore, by observing students' performance in project tasks-such as teamwork, problem-solving, and innovative thinking-process evaluation of their comprehensive abilities can also be conducted. Professional competency evaluation is equally a crucial component of the system, encompassing professional ethics, sense of responsibility, safety production awareness, teamwork, and communication skills. Through various methods including routine teacher observation, student self-assessment and peer assessment, and even the introduction of enterprise evaluation, combined with students' actual performance in classroom learning, practical training, and project completion, a comprehensive understanding of their professional competency development can be achieved.

4.3.2. Strengthening Process Evaluation

Within the framework of the "1+X" Certificate System, the teaching process places greater emphasis on tracking and evaluating students' learning progress, focusing on their improvement and growth. Process evaluation can promptly reflect learning status, providing a basis for dynamically adjusting teaching arrangements. In practice, learning effectiveness can be timely assessed through methods such as regular quizzes and monthly project progress reviews. This phased feedback helps teachers quickly identify problems students may have in areas like knowledge comprehension or skill operation, thereby providing targeted guidance and assistance. Establishing student learning portfolios serves as vital support for process evaluation. Portfolios can systematically record information such as students' classroom participation, homework completion quality, project implementation process, and various assessment scores. With learning portfolios, teachers can comprehensively grasp students' learning trajectories, enabling continuous tracking and evaluation; students can also clearly see their own progress, identify strengths and weaknesses, and thus adjust their learning strategies more purposefully. Furthermore, by utilizing informational tools such as online learning platforms and teaching management systems, learning behavior data-such as online learning duration, discussion participation, and assignment submission status-can be collected in real-time. Teachers can analyze students' learning processes based on this data, promptly identifying potential problems and actual needs, and subsequently flexibly adjusting teaching strategies and methods to tangibly enhance teaching effectiveness.

5. Conclusion

Guided by the "1+X" Certificate System, a series of teaching reform explorations have been conducted for the NC Programming and Machining course in higher vocational education. Regarding curriculum system optimization, the course content was meticulously reorganized and integrated around the vocational skill level standards for NC turning and milling. A tiered teaching framework comprising "Foundation - Intermediate - Advanced" modules was constructed. This structure accommodates the learning needs of students at different levels and lays a solid foundation for them to obtain corresponding vocational skill level certificates.In terms of teaching methods and tools, informational teaching tools such as NC simulation software and online teaching platforms were actively introduced. These tools have enriched teaching resources and formats, enhancing the interactivity and effectiveness of instruction. Concurrently, a diversified evaluation system encompassing knowledge, skills, and professional competency was established. By combining teacher assessment, student self- and peer-assessment, and enterprise evaluation, the comprehensiveness and objectivity of the assessment were achieved. Furthermore, a dynamic evaluation mechanism was implemented. Based on students' learning processes and certificate assessment outcomes, teaching strategies were promptly adjusted to provide personalized guidance and support for students, thereby effectively promoting their holistic development.

Funding: This paper was supported by Fujian Polytechnic of Information Technology Research Project (No. Y22205).

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