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Original Paper

Exploration on the Reform Path of Project-Based Teaching in Higher Vocational Colleges Based on the SGAVE Concept

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Abstract

In response to the issues of disconnection from industry and one-sided competency development in the teaching of foundational mechanical manufacturing courses in higher vocational education, this study explores project-based teaching reform for the course under the guidance of the Sino-German Advanced Vocational Education Cooperation Project (SGAVE) concept. It systematically analyzes the connotation and characteristics of the SGAVE concept, restructures the course content to align with job requirements, and develops authentic enterprise-related projects. A reform framework is constructed, encompassing "restructuring the curriculum system—innovating teaching methods—developing project-based teaching resources—building a teaching team." A Four-in-One evaluation system integrating "knowledge, skills, literacy, and outcomes" is designed to fully align with the three-dimensional competency development goals of professional, methodological, and social skills. The research demonstrates that the SGAVE concept can effectively promote the shift of higher vocational foundational courses from knowledge transmission to competency development, providing practical references for the reform of foundational courses in mechanical engineering and the localization of the "dual system" in vocational education.

Keywords

SGAVE concept, higher vocational education, foundational mechanical manufacturing, teaching reform, process-oriented approach

1. Introduction

Against the backdrop of China's pursuit of high-quality economic development and ongoing industrial upgrading, vocational education plays an increasingly crucial role in cultivating high-caliber technical and skilled professionals. Introducing advanced vocational education concepts and teaching models has become a vital pathway to enhance the quality of vocational education. The SGAVE concept originates from Germany's well-established "dual-system" vocational model, emphasizing deep integration between schools and enterprises, and focusing on the integrated development of students' practical abilities and professional competencies (MA, C. Y., & MA, M. H., 2025). The SGAVE project is jointly promoted by the Ministry of Education and enterprises from Germany and other countries with advanced vocational education systems. It aims to assimilate their expertise and experience in "dual-system" talent development, thereby establishing a high-quality technical and skilled talent cultivation program with international cooperative standards. This project not only supports the high-quality development of regional economies and industries, but also provides solid human resource support for the transformation, upgrading, and high-quality development of China's manufacturing sector (WU, 2023).

Fundamentals of Mechanical Manufacturing is a core foundational course for mechanical majors in higher vocational colleges, playing a crucial role in cultivating students' engineering practical capabilities. Through this course, students acquire essential competencies in material selection and process design, laying a solid foundation for subsequent specialized courses and future careers in mechanical manufacturing. However, traditional teaching of this course still exhibits several shortcomings, such as an overemphasis on theoretical content, relatively weak practical components, and a lack of diversity in teaching methods. These limitations hinder its alignment with the current manufacturing industry's demand for high-quality technical and skilled professionals. Therefore, implementing project-based teaching reform in the Fundamentals of Mechanical Manufacturing course based on the SGAVE concept carries pressing relevance and significant importance.

2. The Connotation and Characteristics of the SGAVE Concept

2.1 Connotation of the SGAVE Concept

Derived from the German "dual-system" vocational education model, the core of the SGAVE concept can be summarized as "competency-oriented, project-practice-based, and school-enterprise-collaboration-guaranteed," emphasizing the integration of the learning process with real-world work processes. The concept primarily encompasses the following aspects: First, competency-based orientation, which is grounded in the authentic demands of professional positions. It focuses on the integrated development of students' "professional competence, methodological competence, and social competence," rather than remaining at the level of mere knowledge transmission (WANG, H. J., LIU, H., & WANG, K., 2024). Second, project-driven learning, where instruction is organized around authentic or simulated vocational projects. Students acquire relevant knowledge and skills by completing specific project tasks, embodying the principle of "learning by doing."Third, school-enterprise collaboration, in which enterprises engage deeply throughout the entire teaching process. They not only provide practical production projects, technical mentors, and training facilities but also ensure that teaching content remains synchronized with advancements in industrial technology (ZHENG, X. Y., 2024). Fourth, process-oriented assessment, which focuses not only on final outcomes but also places greater emphasis on the progressive development of students' comprehensive qualities during project implementation. These include problem-solving abilities, teamwork, and communication skills.

2.2 Characteristics of the SGAVE Concept

2.2.1 Student-Centered Approach

The teaching process consistently adopts a student-centered approach, paying close attention to individual differences and actual learning needs. The teacher's role shifts from a one-way transmitter of knowledge to a guide and organizer of the learning process. To fully stimulate students' motivation and initiative, instructors employ diverse teaching methods—such as group discussions, project-based practice, and case analysis—guiding students to effectively master and apply knowledge and skills through independent exploration and teamwork.Taking the project-based teaching of the Fundamentals of Mechanical Manufacturing course as an example: teachers form groups based on students' actual conditions, with each group undertaking a specific project task. During project implementation, the teacher primarily guides students to independently complete stages such as information research, solution design, and hands-on operation, while providing timely guidance and support when challenges arise. Through such practical processes, students can continuously enhance their capabilities within authentic tasks.

2.2.2 Emphasis on Practical Competency Development

Practical competency is central to vocational student training, and the SGAVE concept places particular emphasis on strengthening this through multiple avenues. On one hand, it significantly increases the proportion of practical instruction within the curriculum, allowing students more time to learn and grow through hands-on operation (CHEN, 2025). In the Fundamentals of Mechanical Manufacturing course, practical sessions may account for over half of the total hours. Students genuinely improve their operational skills through authentic training such as operating machine tools and processing parts in training workshops.On the other hand, the concept actively promotes school-enterprise cooperation, expanding internship and employment channels for students. Enterprises not only provide real workplace scenarios and project tasks but also enable students to become familiar with production processes and management models through actual participation, thereby accumulating experience and enhancing professional (LV, Q. L., CHEN, W. J., & JIANG, H., 2024).

3. Analysis of the Characteristics and Issues in the Fundamentals of Mechanical Manufacturing Course

3.1 Characteristics of the Course

The Fundamentals of Mechanical Manufacturing course covers a broad range of content, encompassing core areas such as machining processes, material forming, and metal-cutting principles. It is designed to help students systematically grasp foundational knowledge in mechanical manufacturing, thereby laying a solid groundwork for subsequent specialized courses.Through this course, students not only understand the principles and applications of various processing techniques and master the properties and selection criteria of metal materials, but also learn to rationally select materials and processes based on part requirements. Furthermore, the course emphasizes cultivating students' preliminary abilities in process design and analysis, enabling them to formulate processing procedures for simple parts, analyze potential issues during machining, and propose corresponding solutions.In terms of practical skill development, the course attaches importance to enhancing students' hands-on abilities through experiments and practical training. Students will have the opportunity to operate common machine tools such as lathes and milling machines to complete the machining and assembly of simple parts. This practical process helps foster a rigorous scientific attitude and sound professional , preparing them thoroughly for future careers in mechanical manufacturing.

3.2 Analysis of Teaching Issues Based on the SGAVE Concept

From the perspective of industry-education integration emphasized by the SGAVE concept, evident shortcomings persist in the current teaching of the Fundamentals of Mechanical Manufacturing course.On one hand, there is generally insufficient enterprise involvement and a lack of deep collaboration between schools and enterprises. In key areas such as curriculum design, teaching method selection, and practical instruction, enterprises often participate only marginally, failing to fully leverage their advantages in real production environments and technical practice. Consequently, students have limited opportunities to learn and train in work settings that closely resemble actual industry conditions. On the other hand, schools often lack sufficient communication with enterprises when developing talent cultivation plans, leading to a misalignment between educational objectives and actual industry needs. Enterprises' production technical standards and real-world projects are not systematically integrated into the teaching content, resulting in a disconnect between the knowledge students acquire and job requirements. Graduates frequently require an extended period to adapt to their professional roles.

Regarding the curriculum system, a gap exists compared to the work-process-based curriculum development philosophy. The current system remains centered on disciplinary knowledge, prioritizing the systematicity and completeness of knowledge while neglecting the demands of actual work processes.The arrangement of course content is not closely aligned with the job tasks and competency requirements of vocational positions. This makes it difficult for students to connect the knowledge they learn with practical work. In teaching the machining processes section, instruction often follows the textbook's chapter sequence, explaining various processing methods in turn, rather than organizing content according to the actual workflow of part manufacturing. This approach leaves students with a fragmented understanding of the entire machining process (LI, K. C., & TIAN, Y. Y., 2024).

In terms of the teaching faculty, there is also a misalignment with the requirements of the SGAVE concept. Some instructors lack practical enterprise experience. Their teaching content is confined to textbook knowledge, and they are unable to integrate real-world cases and experiences into their instruction. With limited understanding of the latest industry developments and technological achievements, they struggle to cultivate students' practical and innovative abilities.Some teachers who enter vocational colleges directly after university graduation have no prior work experience in enterprises. They lack an in-depth understanding of the actual production processes and technology applications in the mechanical manufacturing industry. Consequently, their teaching tends to be strictly textbook-based, failing to provide students with vivid and practical instructional content.Furthermore, schools often inadequately emphasize teacher training and development and lack effective incentive mechanisms. This results in low motivation among teachers to engage in enterprise practice and teaching reform. Simultaneously, teachers have limited opportunities for continuous learning and self-improvement, making it difficult for them to meet the demands placed on educators under the SGAVE concept.

4. Pathways for Project-Based Teaching Reform Based on the SGAVE Concept

4.1 Restructuring the Curriculum System

A systematic analysis of the Fundamentals of Mechanical Manufacturing course was conducted, guided by the actual workflow of mechanical manufacturing enterprises. A curriculum development team, composed of enterprise experts and key faculty members, carried out in-depth research in multiple companies across sectors such as automotive, machine tool, and mold manufacturing. Through exchanges with frontline technicians and workshop managers, the team gained a detailed understanding of the end-to-end production process, from design and R&D, raw material procurement, and processing/manufacturing to quality inspection, assembly, and debugging.

Based on the research findings, the course content was reintegrated into several project modules centered on authentic work tasks. Taking the Mechanical Part Machining project as an example, this module comprehensively covers the entire process from drawing analysis, process design, tool and fixture selection, machine operation, to quality inspection.In the drawing analysis phase, students must apply their knowledge of mechanical drawing to accurately interpret part geometry, dimensions, and tolerances, thereby clarifying machining requirements and technical challenges. During the process design stage, they need to comprehensively consider material properties, structural characteristics, and production batch size to rationally select machining methods and sequences, formulating a detailed process route. For tool and fixture selection, students must choose appropriate tool types, parameters, and fixture structures based on the process plan and part features to ensure machining accuracy and efficiency. In practical operation, students are required to skillfully master equipment such as lathes and milling machines to complete part processing according to specifications. Finally, in the quality inspection phase, using various measuring tools and methods, they inspect the dimensional, geometric, and positional accuracy of the parts to determine compliance with design requirements.

Each project module is further divided into specific learning scenarios, each with defined learning objectives, work tasks, and assessment criteria. By completing practical tasks within these scenarios, students progressively master relevant knowledge and skills, achieving a transition from theory to practice. Simultaneously, the course emphasizes cultivating students' engineering thinking, problem-solving, and teamwork abilities. This enables them to comprehensively apply what they have learned to analyze and solve problems encountered in real work during project completion, thereby holistically enhancing their professional competency.

4.2 Application of Action-Oriented Teaching Methods

In teaching the Fundamentals of Mechanical Manufacturing course, action-oriented teaching methods such as project-based learning, case-based teaching, and role-playing are actively employed. This aims to fully engage students' learning initiative and effectively cultivate their ability to solve practical problems.The project-based teaching method uses authentic projects as the vehicle, decomposing course content into a series of tasks. For instance, in the Mechanical Part Machining project, the teacher provides specific machining requirements. Students then collaborate in groups to independently complete the entire process, from information research, process design, and equipment selection to tool preparation, part machining, and inspection. Throughout this process, students are required to proactively identify problems, analyze them, and attempt solutions, while the teacher primarily acts as a guide and facilitator. Through this "learning by doing" approach, students can organically integrate theoretical knowledge with practical skills, effectively enhancing their hands-on capabilities and problem-solving abilities in real contexts.

The role-playing method simulates real work scenarios, helping students experience the responsibilities of different positions and improving their communication and teamwork skills. For example, in Mechanical Assembly instruction, students assume roles such as assembly workers, quality inspectors, and process engineers, collaborating to complete assembly tasks and quality inspection work[8]. In this process, they need to communicate and coordinate with different roles, thereby gaining a more authentic understanding of real work requirements and strengthening their professional and job adaptability.

4.3 Implementation of Integrated Theory-Practice Teaching

Establishing an integrated theory-practice teaching environment, which organically combines theoretical instruction with practical training, is a crucial guarantee for improving the teaching quality of the Fundamentals of Mechanical Manufacturing course. The training base is designed according to the layout of an actual production workshop, featuring functional zones such as machining, assembly, and inspection areas, allowing students to conduct practical operations in an authentic production setting.During the teaching process, the boundary between theoretical and practical instruction is dissolved by integrating theoretical knowledge into practical training, enabling students to deepen their understanding of theory through practice. For instance, when explaining the Principles of Metal Cutting, the teacher can combine this with machine tool operation practice, allowing students to personally experience the impact of parameters such as cutting force and cutting temperature on machining quality. Through hands-on operation, students can better grasp the relevant knowledge of metal cutting principles.

In integrated theory-practice teaching, instructors should focus on guiding students to think and summarize, fostering their self-directed learning and innovative abilities. During practical operations, teachers should guide students to identify, analyze, and solve problems, encouraging them to propose their own insights and innovative ideas. Teachers must also provide timely evaluation and feedback on students' practical work, helping them continuously refine and improve their practical skills.

4.4 Development of Project-Based Teaching Resources

Guided by the SGAVE concept, a Dual School-Enterprise Teaching Resource Development Team was established in collaboration with mechanical manufacturing enterprises. The team's core responsibilities are to "research enterprise needs, develop teaching projects, and design teaching resources," ensuring the resources' alignment with industry and their practicality for hands-on operation. Following a three-step process of "Enterprise Demand Research→Project Screening→Project Transformation," a project repository for the Fundamentals of Mechanical Manufacturing course was developed.

In the Enterprise Demand Research phase, the team conducted in-depth visits to partner enterprises. Through "workshop visits, job task analysis, and technician interviews," they collected information on enterprises' mechanical manufacturing production orders, technical challenges, and job skill requirements. During Project Screening, suitable projects were selected from the collected enterprise demands based on the knowledge and skill objectives of the Fundamentals of Mechanical Manufacturing course. Screening criteria included: coverage of core course knowledge points, operational feasibility, and alignment with job skill requirements. In Project Transformation, authentic enterprise projects were converted into teaching projects, clearly defining the "teaching objectives, task breakdown, implementation steps, and assessment criteria" for each.

Taking the transformation of the enterprise order Cutting Machining of an Automotive Wheel Hub Bearing Seat into a teaching project as an example: the teaching objectives were set to master skills in cutting process design, conventional lathe operation, and part quality inspection. The tasks were decomposed into: drawing interpretation→process design→tool selection→lathe operation→quality inspection. The implementation steps were divided into: school-based theoretical learning → enterprise-based practical operation→school-based summarization. The assessment criteria referenced the enterprise's Part Machining Quality Standards. The final project repository is categorized by "progressive difficulty" into Basic, Intermediate, and Comprehensive Projects. Basic projects correspond to the early stage of the course, Intermediate to the mid-stage, and Comprehensive to the later stage, meeting the teaching needs of different phases.

5. Constructing a Multidimensional Teaching Evaluation System

5.1 Design of the Evaluation Indicator System

To align with the SGAVE concept's requirements for career-orientation and school-enterprise collaboration, a comprehensive evaluation system integrating the four dimensions of "knowledge, skills, competency, and outcomes" has been constructed. Industry mentors are incorporated into the evaluation process to ensure the objectivity and comprehensiveness of the assessment results, thereby accurately reflecting students' professional capabilities.

Table 1. The Integrated Four-Dimension Evaluation System

Evaluation Dimension	Evaluation Content	Evaluating Entity	Evaluation Method	Weight
Theoretical Knowledge	Mastery of project-related theoretical knowledge	School Instructor	Formative Tests + Theoretical Report Scoring	20%
Practical Skills	Standardization in simulated training operations, proficiency in enterprise operations, and accuracy in quality inspection	School Instructor + Industry Mentor	Simulated Training Software Scoring + On-site Enterprise Practice Scoring	35%
Professional Competency	Awareness of standardized operations, safety responsibility, and teamwork ability	Industry Mentor + Peer Assessment within Groups	On-site Observation Scoring by Industry Mentor + Intra-group Peer Assessment	25%
Project Outcomes	Completeness and rationality of the process design report, quality of the machined product, and performance in project defense	School Instructor + Industry Mentor	Outcome Report Scoring + Finished Product Quality Scoring + Defense Presentation Scoring	20%

5.2 Evaluation Implementation Process

A combination of formative and summative evaluation is adopted, applied throughout the entire project implementation to ensure a dynamic and comprehensive assessment.

5.2.1 Formative Evaluation

Project Log Recording: Students are required to maintain daily project logs, documenting task completion, problems encountered, solutions applied, and learning reflections. Instructors/industry mentors review logs weekly, scoring aspects such as the problem-solving process and self-directed learning engagement.

Stage Outcome Review: At the midpoint of each project module, a stage outcome review session is convened. Student groups present progress on their technical solutions, completed operations, and inspection results. The dual mentors provide improvement suggestions focusing on process feasibility and quality control, and score the stage outcomes against the evaluation criteria.

Daily Performance Documentation: Through classroom observation and tracking during enterprise practice, instructors/industry mentors document student behaviors related to social competencies, such as teamwork, adherence to safety protocols, and communication skills.

5.2.2 Summative Evaluation

Project Outcome Defense: Upon completion of all projects, a final defense is organized. Student groups present the project implementation process, achieved competencies, and process improvement outcomes via PPT. The dual mentors pose questions and assign scores targeting professional competence (e.g., part quality inspection data), methodological competence (e.g., problem-solving logic), and social competence (e.g., rationality of team division of labor).

Enterprise Practice Evaluation: Industry mentors complete an Enterprise Practice Evaluation Form based on students' technical application ability and professional conduct during the practicum. The assessment focuses on whether students can apply school-acquired knowledge to actual enterprise production and their alignment with occupational norms.

Comprehensive Competency Assessment: Scores from formative and summative evaluations are combined using predefined weights to calculate the final grade. Concurrently, a three-dimensional competency evaluation report is generated. This report clarifies students' strengths and weaknesses in professional, methodological, and social competencies—for instance, noting that "part machining accuracy meets standards in professional competence, but process optimization and innovation are lacking in methodological competence"—and provides targeted improvement suggestions.

5.3 Application of Evaluation Results

The evaluation results serve not only to measure student learning outcomes but also to facilitate teaching improvement, student development, and curriculum optimization, thereby forming a closed loop of "evaluation→feedback→improvement."

Student Level: The three-dimensional competency evaluation report is provided to students to guide the formulation of personalized learning plans. For example, students identified with "deficient process optimization ability" may be recommended to join interest groups in advanced manufacturing technology or participate in enterprise process improvement projects. Furthermore, evaluation results are linked to recommendations for skills competitions and internships. Top-performing students receive priority recommendations for vocational skills competitions and internships at high-quality partner enterprises.

Teaching Level: Overall class evaluation data are aggregated and analyzed for score distribution across indicators. For instance, if the average score for "part quality compliance rate within professional competence" is low, instructors reflect on potential shortcomings in quality control guidance during practical training. Teaching plans are then adjusted, such as by increasing hands-on training hours for quality inspection or incorporating more enterprise quality management cases. If scores for "self-directed learning ability within methodological competence" are low, the design of "independent inquiry tasks" is optimized by providing clearer guidance on literature search directions and industry standard references.

Curriculum Level: Informed by evaluation results and enterprise feedback, course content and project modules are updated. For example, if feedback on a "comprehensive manufacturing project" indicates that "students lack support from real-world cases," collaboration with enterprises is enhanced to include "physical product demonstrations and special lectures by enterprise technical staff." If new cutting tool materials emerge in the industry, the related task on cutting tool material selection is updated accordingly, ensuring the curriculum remains synchronized with technological advancements.

6. Conclusion

This study conducted an in-depth exploration of project-based teaching reform for the Fundamentals of Mechanical Manufacturing course in higher vocational colleges, grounded in the SGAVE concept. By integrating this concept into course instruction, the curriculum system was restructured to be guided by the actual workflows of mechanical manufacturing enterprises. The course content was consolidated into multiple project modules and learning scenarios, ensuring close alignment with occupational demands. This significantly enhanced the course's practicality and relevance.In the realm of teaching method innovation, action-oriented teaching methods were actively introduced into the classroom. This not only effectively stimulated students' learning enthusiasm and motivation for self-directed learning but also rigorously trained their practical operational skills and innovative thinking through hands-on practice.Through a series of teaching reform practices, students' comprehensive competencies demonstrated a marked improvement. Concurrently, the teaching capacity of the faculty was enhanced. Their pedagogical concepts were progressively updated, teaching methods continuously refined, and their own practical teaching abilities further strengthened.

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