A Study on the Core Competencies of Vocational Automotive Maintenance Students amidst the Construction of a Skill-Centric Society

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Abstract: This study investigated the developmental characteristics of professional core competencies among vocational automotive repair students. A quantitative analysis was conducted using a Core Competencies Self-Assessment Questionnaire, administered to a sample of 300 students from two vocational colleges in Taizhou City. The dataset for analysis comprised 271 valid responses, yielding a response rate of 90.33. The findings revealed significant gender-based disparities. Independent samples t-tests indicated that male students significantly outperformed their female counterparts in both practical ability (t = -2.483, p < .05) and job creativity (t = -2.397, p < .05). Although male students exhibited marginally higher mean scores in the remaining competency domains, these differences were not statistically significant. Concerning variations across academic years, a one-way analysis of variance (ANOVA) demonstrated that none of the ten core competencies exhibited statistically significant differences based on grade level. However, an analysis of mean score trends indicated that the highest levels of practical ability and problem-solving skills typically manifested in either the foundational or final years, suggesting a potential adaptive adjustment phase during the intermediate years of the program.

Keywords: Core Competencies; Automotive Technology; Vocational Colleges; Skills-Based Society

1. Introduction

China's Education Modernization 2035 outlines the strategic objective of fundamentally achieving education modernization by 2035, establishing China as a leading power in education, and propelling the nation to become a society of lifelong learners, a country rich in human resources, and a nation with a formidable talent pool. Against the backdrop of ongoing reforms in vocational education, enhancing the quality of talent cultivation in higher vocational education has emerged as a pressing concern for institutions across this sector. Higher vocational colleges, serving as crucial venues for delivering advanced vocational education, bear the direct responsibility for elevating the caliber of trained professionals [1]. The Automotive Maintenance specialty, a significant component within the vocational education system, currently confronts the dual challenges of technological transformation and evolving industry demands. The deepening advancement of Industry 4.0, the widespread adoption of electric vehicles, and the rapid development of intelligent connected vehicles are collectively accelerating the automotive industry's transition towards digitalization and smart technologies. Consequently, the traditional automotive repair education model, predominantly focused on mechanical maintenance, is increasingly inadequate for meeting the industry's complex requirements for high-quality technical and skilled talent possessing integrated competencies.

Under the context of a skills-based society, the cultivation of professional core competencies has emerged as a key solution to addressing the challenges in talent development. It necessitates that students not only consolidate "hard skills" in traditional mechanical repair but also focus on developing a complex of "soft skills" essential for adapting to technological iterations and complex work scenarios. These specifically include professional ethics, safety responsibility awareness, teamwork consciousness, communication skills, learning capacity, adaptability, and innovative ability [2]. These core competencies serve as both the fundamental support for students to tackle challenges in emerging roles, such as fault diagnosis in intelligent connected vehicles and maintenance of new energy systems, and the crucial guarantee for their sustainable career development. Based on this, our study focuses on the developmental characteristics of core competencies among higher vocational automotive engineering technology students, aiming to investigate their differential manifestations across the two dimensions of gender and academic year, thereby providing a basis for the design of targeted training programs.

2. Examining the Constructs of Professional Core Competencies in Automotive Engineering Technology Students at Vocational Colleges

The identification of core competencies is grounded in a profound understanding of industry evolution and job requirements, ensuring a close alignment between instructional content and market demands [3]. This study utilized a Core Competencies Self-Assessment Questionnaire, which comprises ten distinct dimensions: Interpersonal Skills, Organizational Management, Practical Operation, Communication Skills, Digital Tool Application, Influence, Written Expression, Research Capability, Job Creativity, and Problem-Solving. Each dimension corresponds to an independent subscale, collectively forming an assessment framework with ten measurement dimensions.

The study employed a grade-stratified random sampling method, recruiting a cohort of 300 automotive engineering technology students from two vocational colleges in the Taizhou region. Electronic questionnaires were administered via the Questionnaire Star platform, resulting in the collection of 271 valid responses, which yielded an effective response rate of 90.33%. Subsequent data analysis was performed using the SPSS 19.0 statistical software package to systematically examine the structural characteristics of the core competencies and their differential manifestations across key demographic variables.

2.1 Interpersonal Skills of Automotive Engineering Technology Students

Interpersonal skills within the automotive engineering technology field refer to the competency required to establish effective interactive relationships with customers, colleagues, and cross-departmental personnel. This encompasses understanding customer needs, service etiquette, emotional management, and team integration, forming the foundation for maintaining customer trust and fostering workplace collaboration. Descriptive statistics for the interpersonal skills of students, categorized by gender and academic year, are presented in Table 1. Analysis from the gender dimension revealed that male students' interpersonal skills were marginally higher than those of their female counterparts. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -0.349, p = 0.728). Regarding variations across academic years, first-year students demonstrated the highest level of interpersonal skills, with third-year students exhibiting a comparable level. In contrast, second-year students displayed a relatively weaker competency in this domain.

Table 1. Means of Interpersonal Skills by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	18.94	3.05
Female	n=10	18.60	2.88
Year 1	n=110	19.14	2.93
Year 2	n=79	18.44	3.06
Year 3	n=82	19.12	3.16
Total	N=271	18.93	3.04

2.2 Organizational Capacity of Automotive Engineering Technology Students

Organizational capacity within the automotive engineering technology profession encompasses the abilities to prioritize maintenance tasks, coordinate the allocation of workshop resources (e.g., equipment, tools, time), and plan work processes. This skillset addresses the foundational management requirements for roles such as maintenance team leader or technical supervisor. Descriptive statistics for students' organizational capacity, categorized by gender and academic year, are presented in Table 2. Analysis from the gender perspective indicated that male students' organizational capacity was marginally higher than that of female students. However, a further independent samples t-test confirmed that this difference was not statistically significant (t = -

0.348, p = 0.728). Regarding developmental trends across academic years, the mean score for organizational capacity showed a slight decline from Year 1 to Year 2, followed by a more pronounced upward trend from Year 2 to Year 3.

Table 2. Means of Organizational Capacity by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.40	3.52
Female	n=10	17.00	5.33
Year 1	n=110	17.33	3.13
Year 2	n=79	17.08	3.69
Year 3	n=82	17.77	4.04
Total	N=271	17.39	3.59

2.3 Practical Competence of Automotive Engineering Technology Students

Practical competence in the automotive engineering technology field pertains to the "hard skills" essential for traditional automotive repair, including the disassembly and reassembly of mechanical components, the standardized use of testing instruments (e.g., oscilloscopes, pressure gauges), and the execution of fault diagnosis procedures. It emphasizes the precision and standardization of operational tasks. Descriptive statistics for students' practical competence, categorized by gender and academic year, are presented in Table 3. Analysis from the gender dimension revealed that male students demonstrated higher practical competence than their female counterparts. A subsequent independent samples t-test confirmed that this difference was statistically significant (t = -2.483, p < .05). Regarding the developmental trajectory across academic years, students' practical competence exhibited an initial period of stability followed by a declining trend.

2.4 Communication Skills of Automotive Engineering Technology Students

Communication skills within the automotive engineering technology discipline encompass the oral explanation of technical issues, the clear articulation of maintenance plans, and the efficiency of information exchange in interdisciplinary team collaboration, requiring a balance between professionalism and accessibility. Descriptive statistics for students' communication skills, categorized by gender and academic year, are presented in Table 4. Analysis from the gender dimension indicated that male students scored higher than female students in communication skills. However, a subsequent independent samples t-test established that this difference was not statistically significant (t = -1.300, p = 0.195). From the perspective of academic year progression, a one-way analysis of variance (ANOVA) revealed a statistically significant main effect of academic year on communication skills ($F_{(2, 268)} = 3.42$, $p < .05$, $\eta^2 = 0.025$). Post hoc multiple comparisons demonstrated that first-year (Year 1) students scored significantly higher than second-year (Year 2) students. While third-year (Year 3) students' scores were higher than those of second-year students, no significant difference was found between third-year and first-year students. The observed effect size ($\eta^2 = 0.025$) falls within the small range, suggesting that while the differences are statistically significant, their practical impact may be limited.

Table 3. Means of Practical Competence by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.37	3.53
Female	n=10	14.50	4.99
Year 1	n=110	17.44	3.48
Year 2	n=79	17.30	3.59
Year 3	n=82	16.99	3.85
Total	N=271	17.26	3.62

Table 4. Means of Communication Skills by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	18.41	3.30
Female	n=10	17.00	4.90
Year 1	n=110	18.77	2.82
Year 2	n=79	17.65	3.72
Year 3	n=82	18.49	3.62
Total	N=271	18.36	3.37

2.5 Digital Literacy among Automotive Engineering Technology Students

Digital literacy within the automotive engineering technology field specifically encompasses three core dimensions: First, digital diagnostic skills, which involve the precise operation of professional equipment such as OBD-II diagnostic scanners and oscilloscopes to read vehicle ECU data streams, and the use of decoding software to interpret fault code logic chains. Second, digital technology application ability, relating to the use of digital twin technology to construct virtual maintenance models for fault simulation and pre-diagnosis, and leveraging cloud computing platforms to access real-time technical support and maintenance solution databases. Third, intelligent system calibration capability, covering advanced digital tasks related to Advanced Driver-Assistance Systems (ADAS). Descriptive statistics for students' digital literacy, categorized by gender and academic year, are presented in Table 5. Analysis from the gender dimension indicated that male students scored higher than female students in digital literacy. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -1.282, p = 0.201). Regarding the developmental trajectory across academic years, the scores exhibited an initial decline followed by stabilization. The initially "high" score among first-year students may stem from a standardized foundational curriculum. The subsequent "decline" in the second year could be an inevitable adjustment period during the transition to specialized, advanced studies. The final "stabilization" in the third year likely results from practical application and curriculum consolidation. It is noteworthy that the differences between year groups gradually widened with academic progression ($F_{(2,\ 268)}$ = 4.21, p = 0.016, η^2 = 0.031). This pattern may originate from the combined effects of multiple mechanisms, including curriculum tracking, heterogeneity in corporate internship resources, and the divergence of learning motivations among students.

Table 5. Means of Digital Literacy by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.77	3.56
Female	n=10	16.30	3.53
Year 1	n=110	18.00	3.28
Year 2	n=79	17.41	3.67
Year 3	n=82	17.63	3.83
Total	N=271	17.72	3.56

2.6 Influence among Automotive Engineering Technology Students

Influence within the automotive engineering technology profession is primarily demonstrated in non-hierarchical leadership contexts, such as guiding technical decision-making in group projects, coordinating the division of maintenance tasks, and mentoring apprentices. It emphasizes the dual impact of technical authority and team cohesion. Descriptive statistics for students' level of influence, categorized by gender and academic year, are presented in Table 6. Analysis from the gender dimension revealed that the mean score for influence was higher among male students than female students. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -1.329, p = 0.185). Regarding academic year progression, its effect on influence was relatively minor, yet a specific trend was observed: scores were highest in Year 1, lowest in Year 2, and showed a recovery in Year 3. Compared to the trend observed for practical competence, this distinct pattern for influence suggests that it is not solely dependent on professional skill but is also shaped by a combination of other factors, including psychological state, social role, and self-confidence.

Table 6. Means of Influence by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.48	3.42
Female	n=10	16.00	4.47
Year 1	n=110	17.69	2.84
Year 2	n=79	16.90	3.97
Year 3	n=82	17.59	3.70
Total	N=271	17.43	3.47

2.7 Written Expression Skills of Automotive Engineering Technology Students

Written expression skills within the automotive engineering technology discipline encompass the ability to produce various professional documents, including accurately completing maintenance work orders, composing technical reports, and drafting customer repair recommendations. These tasks demand logical clarity and terminological precision. Descriptive statistics for students' written expression skills, categorized by gender and academic year, are presented in Table 7. Analysis from the gender dimension indicated that male students slightly outperformed their female counterparts in written expression skills. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -1.052, p = 0.294).

Regarding academic year progression, a positive developmental trend was observed. Students' written expression skills demonstrated measurable improvement as they advanced through their academic program.

Table 7. Means of Written Expression Skills by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	15.46	3.71
Female	n=10	14.20	4.32
Year 1	n=110	15.32	3.32
Year 2	n=79	15.47	3.82
Year 3	n=82	15.50	4.19
Total	N=271	15.42	3.73

2.8 Research Capability of Automotive Engineering Technology Students

Research capability in the context of automotive engineering technology refers to engagement in innovative activities such as exploring new maintenance technologies, proposing improvements to traditional processes, and developing fault case databases. It reflects the potential for proactive learning and continuous improvement in response to technological advancements. Descriptive statistics for students' research capability, categorized by gender and academic year, are presented in Table 8. Analysis from the gender dimension revealed that male students demonstrated a slightly higher level of research capability than their female counterparts. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -0.337, p = 0.736). Regarding academic year progression, third-year (Year 3) students exhibited the strongest research capability, while second-year (Year 2) students showed the weakest. The impact of academic year on research capability displayed a "U-shaped" trend.

Table 8. Means of Research Capability by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.18	3.55
Female	n=10	16.80	3.01
Year 1	n=110	17.12	3.50
Year 2	n=79	16.82	3.33
Year 3	n=82	17.57	3.75
Total	N=271	17.17	3.53

2.9 Job Creativity of Automotive Engineering Technology Students

Job creativity in the automotive engineering technology profession refers to the ability, within authentic work contexts, to adeptly utilize professional knowledge and skills to identify, analyze, and solve problems through flexible and innovative approaches, ultimately proposing effective solutions. It represents a synthesis of technical proficiency and innovative thinking, and serves as a key characteristic of high-quality automotive repair talent. Descriptive statistics for students' job creativity, categorized by gender and academic year, are presented in Table 9. Analysis from the gender dimension revealed that male students exhibited significantly higher job creativity than female students. A subsequent independent samples t-test confirmed that this difference was statistically significant (t = -2.397, p < .05). Regarding academic year progression, job creativity demonstrated a year-on-year increasing trend. However, the difference between the highest and lowest scoring year groups was merely 0.39, indicating that the influence of academic year on job creativity is relatively limited.

Table 9. Means of Job Creativity by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	16.72	3.55
Female	n=10	13.60	4.62
Year 1	n=110	16.39	3.50
Year 2	n=79	16.71	3.93
Year 3	n=82	16.78	3.52
Total	N=271	16.60	3.63

2.10 Problem-Solving Competence of Automotive Engineering Technology Students

Problem-solving competence in the automotive engineering technology field refers to the comprehensive ability to accurately analyze root causes, develop and implement effective solutions, and ultimately restore vehicle normal operation or optimize performance when confronted with automotive faults, maintenance challenges, detection anomalies, system failures, or customer service issues. This process relies on the application of acquired professional knowledge, practical skills, and logical reasoning. Descriptive statistics for students' problem-solving competence, categorized by gender and academic year, are presented in

Table 10. Analysis from the gender dimension revealed that male students demonstrated higher problem-solving competence than female students. However, a subsequent independent samples t-test confirmed that this difference was not statistically significant (t = -1.313, p = 0.190). Regarding academic year progression, the impact of academic year on problem-solving competence exhibited a "U-shaped" trend. Third-year (Year 3) students displayed the strongest competence, while second-year (Year 2) students showed the weakest. The difference between the highest and lowest scoring year groups was 0.87, indicating a moderate influence of academic year on the development of this competence.

3. Existing Issues and Contributing Factors in Core Competencies of Higher Vocational Automotive Technology Students

3.1 Existing Issues

Across all core competency dimensions, male students demonstrated marginally higher mean scores than their female counterparts. Although most of these differences did not reach statistical significance, the consistent trend suggests a potential gender-based divergence in skill acquisition. Notably, in the dimensions of practical competence and job creativity, male students significantly outperformed females, indicating that female students face greater challenges in hands-on operation and innovative problem-solving.

Table 10. Means of Problem-Solving Competence by Gender and Academic Year

Variable	N/n	*M*	*SD*
Male	n=261	17.67	3.46
Female	n=10	16.20	3.91
Year 1	n=110	17.83	3.04
Year 2	n=79	17.03	3.50
Year 3	n=82	17.90	3.97
Total	N=271	17.62	3.48

The practical competence of higher vocational automotive technology students exhibited an initial period of stability followed by a decline. Third-year students had a lower mean score than first- and second-year students, indicating a deficiency among senior students in maintaining and refining traditional "hard skills." Communication skills showed a marked dip in the second year, falling below the levels of both first and third years. This suggests that communication training may be neglected as academic pressure from specialized courses intensifies, leading to a regression in expression and collaboration abilities. Research capability displayed a "U-shaped" trend, with second-year students at the lowest point. While a recovery was observed in the third year, the overall level remains suboptimal, pointing to insufficient research guidance and practical opportunities for students in the intermediate years. Although written expression skills showed some improvement across academic years, the overall proficiency was low (the highest mean being only 15.50), and the rate of improvement was limited, reflecting inadequate training in writing and documentation standards.

The overall low levels of written expression skills and research capability indicate insufficient student proficiency in text-based and research-oriented tasks such as technical documentation writing, fault case summarization, and innovation proposal drafting. This inadequacy hinders their future preparedness for compound roles in technical management, training, or technical improvement. While job creativity showed a slight improvement across years, the overall level is not high, and the difference between the highest and lowest years is minimal. This suggests that the current teaching model inadequately fosters innovative thinking and flexible problem-solving skills. Although digital literacy scores were mid-to-high range, they remain insufficient to meet the rapid demands of automotive industry digitalization and smart transformation, particularly concerning the underdevelopment of advanced digital tool application skills.

Organizational capacity showed a slight decline from the first to the second year, with some recovery in the third year. However, the overall mean scores were not high, indicating that students' abilities in task prioritization, resource coordination, and team management remain relatively weak. This weakness is detrimental to their future preparedness for supervisory roles such as maintenance team leader or technical supervisor. The influence dimension also showed generally moderate mean scores, with the lowest point among second-year students. This suggests that students' non-authority leadership, technical decision-making guidance, and influence within team collaborations have not been effectively cultivated, potentially impacting their future ability to assume core roles within teams.

3.2 Analysis of Contributing Factors

The current curriculum system in higher vocational automotive technology programs remains predominantly focused on "hard skills" such as automotive mechanical structures, fault diagnosis, and maintenance operations. Although practical teaching constitutes a significant portion, there is comparatively less emphasis on "soft skills" like communication, teamwork, technical reporting, and project management. Simultaneously, there is a notable deficiency in course offerings dedicated to higher-order competencies such as digital tool application, technical research, and innovative thinking, resulting in students being underprepared when confronting modern automotive technologies.

The predominant teaching methodology still relies heavily on teacher-led instruction and student imitation of operations. There is insufficient application of student-centered approaches like project-based learning (PBL), problem-based learning (PBL), and case-based teaching. Consequently, students lack adequate opportunities for independent inquiry, technical summarization, and expressive output, leading to the slow development of research capability, written expression skills, and innovation ability. Particularly in the intermediate and senior years, as course difficulty increases, students' learning motivation and sense of purpose can decline, contributing to the regression observed in some skills.

Despite the inclusion of components like enterprise internships and graduation projects, most internship content emphasizes basic operations and lacks comprehensive projects that tightly integrate with real-world work scenarios, such as complex repairs, customer communication, and teamwork collaboration. This gap prevents students from effectively integrating and applying the various core skills learned in the classroom, manifesting as shortcomings particularly in organizational coordination, comprehensive problem-solving, and communication feedback.

Although the research data indicate that most gender differences are not statistically significant, the slight male advantage in most skills, coupled with the relatively weaker performance of female students in certain skills (e.g., practical, creative, digital), may be influenced by factors such as traditional gender role stereotypes and implicit biases in teaching attention. These factors may result in female students lacking sufficient encouragement and targeted training in some critical competencies.

4. Strategies for Enhancing Core Competencies in Automotive Engineering Technology Students at Higher Vocational Institutes

4.1 Addressing Gender Differences and Implementing Personalized Skill Guidance Strategies

In response to the significant gender disparities observed in practical competence and job creativity, along with the slight male advantage in most skills, it is imperative to move beyond a "one-size-fits-all" teaching model and provide differentiated support. To address the lower practical competence among female students, establish a "Female Technician Development Program." This program would utilize small-group and one-on-one mentoring to reduce apprehension towards hands-on tasks and build operational confidence. Design "innovation tasks from a female perspective," such as "Optimizing Maintenance Processes for Female User-Friendliness" or "Ergonomic Interior Modification Solutions." These tasks aim to leverage potential female strengths in detailed observation and user experience, encouraging the proposal of personalized solutions. Activities like career role model sharing sessions and group counseling can help break down the stereotype that "automotive repair is a male-dominated field" and enhance female students' self-efficacy in learning technical skills. For male students, who showed marginally higher but not significantly different scores in soft skills like communication and interpersonal abilities, incorporate tasks such as "customer service simulations" and "cross-team collaboration projects." These are designed to strengthen the ability to explain technical concepts in accessible language and foster inclusivity in teamwork. Encourage male students to participate in activities like "Technical Improvement Proposal Development" and "Innovative Application of Digital Tools" to prevent over-reliance on experiential knowledge and neglect systematic thinking.

4.2 Constructing a Tiered Development Plan by Academic Year to Precisely Address Critical Skill Development Periods

In response to the differentiated trends observed in core competencies across academic years, a tiered development pathway of "Building Foundations in Year 1, Strengthening Adaptation in Year 2, and Promoting Mastery in Year 3" is designed to strategically address the adaptive challenges specific to each stage.

Year 1: Building foundations and strengthening introductory core skill training

Focus on the standardized cultivation of foundational skills such as practical competence, digital literacy, and written expression, establishing a dual-track teaching model that integrates "Theory + Operation." Offer practical courses like "Fundamental Automotive Structure and Disassembly/Assembly" and "Basic Diagnostic Equipment Use," aiming to solidify basic operational procedures through standardized process training. Building upon the traditional core of professional knowledge and skills, incorporate the cultivation of critical competencies such as critical thinking, teamwork, communication skills, and innovative thinking. By designing diverse teaching activities and projects, students can experience, learn, and enhance these core qualities through practice [4].

Year 2: Focusing on adaptation and overcoming the "performance trough"

Address the decline or plateau in competencies like practical ability, problem-solving, and influence observed in the second year through targeted training and interdisciplinary integration to enhance comprehensive application skills. Design comprehensive training projects such as "Complex Fault Diagnosis" and "Multi-system Interaction Analysis," utilizing authentic or simulated complex problems to foster students' logical reasoning and coordinated application of multiple skills. Increase "Group Collaborative Tasks," employing role-playing (e.g., team leader, technician, recorder) to specifically enhance influence and organizational capacity. Conduct "Learning Strategy Guidance" sessions to help students adapt to the steep increase in specialized course difficulty, alleviating skill stagnation caused by divided attention.

Year 3: Deepening application and aligning with workplace demands

Focus on skills directly relevant to professional roles, such as job creativity, problem-solving competence, and communication skills, facilitating skill transfer and advancement through enterprise internships and graduation projects. Implement a "Post-Following Internship + Project-Based Learning" model, engaging students in real maintenance cases to enhance job creativity and technical decision-making abilities through solving practical problems. Integrate requirements within the graduation project for students to produce technical documentation and present solutions, specifically strengthening written expression and communication skills. Invite industry technicians to lead "Advanced Skill Workshops," transmitting practical experience through a "master-apprentice" approach to bridge the skill gap between the classroom and the workplace.

4.3 Innovating Teaching Models to Strengthen “Learning by Doing” and “Creating through Learning”

To address the current need for improving the core skills of automotive repair majors, a curriculum system characterized by "hierarchical core skills, layered core courses, and segmented training processes" has been constructed. Diverse combined models such as "Do-Learn-Teach," "Do-Train-Educate," and "Teach-Learn-Educate" are adopted for talent cultivation [5]. In line with the practical and creative nature of core skills, teaching methods are being shifted from traditional "knowledge impartation" towards "capacity generation," so as to enhance students' comprehensive professional competence.

4.3.1 Normalization of project-based learning

The project-oriented teaching model drives students to systematically master professional core skills through project tasks [6]. Against the backdrop of Industry 4.0, constructing an integrated theory-practice skills training model led by projects is of significant practical importance [7]. Using authentic or simulated automotive repair problems (e.g., "Intermittent Engine Vibration Troubleshooting," "New Energy Vehicle Charging Abnormality Diagnosis") as carriers, a complete teaching process encompassing "problem definition - solution design-implementation and verification - summary and reflection" is designed. This enables students to comprehensively apply multidimensional abilities, such as communication and collaboration, practical operation, and research innovation in the process of solving complex real-world problems.

4.3.2 Deep integration of digital technology

Basic digital skills refer to a set of competencies that enable individuals to perform fundamental tasks using hardware, software, and basic online operations. These skills form the key foundation for acquiring digital literacy and thriving in society and the workplace [8]. Introducing virtual simulation software (e.g., virtual laboratories for automotive fault diagnosis) and digital twin platforms (e.g., engine operation status simulation systems) into teaching helps students overcome the limitations of physical hands-on conditions and deepens their understanding of complex automotive systems. Meanwhile, by engaging in data analysis tasks (e.g., optimizing diagnostic processes based on cloud-based maintenance data), students' digital application capabilities and research innovation skills are further enhanced.

4.3.3 Deepening school-enterprise collaborative education

Collaboration between schools and enterprises is an effective pathway to promote the integration of education and industry and improve teaching quality [9]. Through jointly establishing programs such as "Ordered Classes" and "Modern Apprenticeships," authentic enterprise job requirements (e.g., maintenance team management, customer complaint handling) are integrated into the curriculum. Inviting enterprise technicians to participate in skill assessments and teaching evaluations ensures the alignment of teaching content with occupational standards. This mechanism not only provides students with authentic scenarios for "learning by doing" but also vigorously promotes the implementation of the "Four Cooperations" talent cultivation model-"Cooperative School Management, Cooperative Education, Cooperative Employment, and Cooperative Development" [10].

5. Conclusion

This study yields the following main conclusions: First, the development of core skills among higher vocational automotive repair students exhibits distinct stage-specific characteristics. Students across different grades show differentiated trends in core skill performance. For instance, practical ability and problem-solving skills are relatively stronger in the first and third years, while a noticeable dip occurs in the second year. Research capability follows a "U-shaped" distribution, peaking in the third year but still showing room for overall improvement. "Soft skills" such as communication and written expression improve slowly with grade progression, yet their overall levels remain low, insufficient to fully meet the demands for versatile technical talent in future job roles. Second, the development of core skills demonstrates skill specificity. "Hard skills" and "innovation skills," such as practical ability and work creativity, are significantly influenced by gender (with male students showing a clear advantage). In contrast, management-related skills like influence and organizational ability are affected by multiple factors, including grade level and psychological state, resulting in prominent uneven development. Third, the current development of students' core skills faces multiple challenges. These include the overall low level of certain key skills (e.g., written expression and research ability), which are inadequate for meeting the demands of intelligent connected vehicle maintenance and technical management positions that require documentation output and innovation proposals. The lag in the development of organizational and influential skills constrains students' future potential for advancement to managerial roles such as technical supervisors or team leaders. Although gender differences are not statistically significant, the slight advantage of male students in practical and innovative areas may be further amplified by differential teaching attention, thereby affecting the full development of related skills among female students.

In response to the above findings, this study proposes the following recommendations: In teaching practice, tiered training plans should be designed according to grade levels, focusing on overcoming adaptive bottlenecks specific to each stage. First-year: Consolidate foundational skills (e.g., practical operation, digital tool application, written expression). Second-year: Emphasize the enhancement of comprehensive application abilities (e.g., complex fault diagnosis, cross-skill collaboration, influence cultivation). Third-year: Deepen job-ready practical capabilities (e.g., work creativity, problem-solving skills, enterprise internship practice). Simultaneously, personalized guidance should be implemented to address gender differences. Initiatives such as "Women Technicians Growth Camps" and "Technical Improvement Proposal" activities can strengthen female students' confidence in practice and innovation, while tasks like "Customer Service Simulation" and "Cross-Team Collaboration" can improve the inclusivity and systematicity of soft skills among male students. Furthermore, it is essential to further optimize the curriculum system by increasing the proportion of courses focused on advanced competencies such as digital tool application, technical research, and team management. Teaching models should transition from "knowledge impartation" to "learning by doing" and "creating through learning" (e.g., normalizing project-based learning, deeply integrating digital technologies, and enhancing school-enterprise collaborative education), thereby comprehensively boosting students' core competitiveness in responding to the transformations in the intelligent connected vehicle industry.

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