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Research on the Application of Integrating Engineering Thermodynamics and Heat Transfer Knowledge with Diesel Engine Knowledge in Military Academy Teaching Based on Data Analysis

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Abstract: Aiming at the characteristics of naval power engineering students in military academies who have a relatively weak theoretical foundation but focus on skill development, this study integrates the essential fundamental theoretical knowledge of engineering thermodynamics and heat transfer with the corresponding professional knowledge of diesel engines. It quantifies their correlation through SPSS data analysis and proposes a teaching model "guided by fault phenomena and maintenance cases, supported by visualization and simulation." The article elaborates on the knowledge point connection method based on data analysis, including descriptive statistics, correlation analysis, and regression modeling, and applies it in combination with the trinity teaching process of "case guidance, project assessment, and practical operation reinforcement." The results show that this integrated method can effectively reduce the difficulty of theoretical learning, stimulate students' interest, enhance fault diagnosis and practical abilities, and provide data support and an effective path for cultivating high-quality technical and skilled marine power engineering talents.

Keywords: Higher vocational teaching; Engineering thermodynamics; Heat transfer; Diesel engine; Data analysis; Teaching application

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1. Introduction

The diesel engine, as the core of the ship's power system, directly affects the vessel's safety and combat effectiveness. Students majoring in marine engineering technology in military academies need to master the principles, structure, operation, and maintenance skills of diesel engines. However, these courses involve a large amount of complex and abstract thermal principles, which rely heavily on the basic professional course "Engineering Thermodynamics and Heat Transfer." A disconnect between basic professional courses and specialized courses is common in higher vocational teaching. Students often find thermal theories boring and abstract, making it difficult to connect them with reality. Therefore, exploring a teaching method that conforms to the cognitive patterns of higher vocational students and closely aligns with job requirements is crucial [1–4].

2. Core knowledge points of Engineering Thermodynamics and Heat Transfer

Engineering thermodynamics and heat transfer are basic courses for the marine engineering technology specialty, with serious logical knowledge points. Based on the principles of SPSS analysis, the core content is divided into three categories: basic concepts, laws and formulas, and key parameters. The variable types are defined, as shown in **Table 1**.

Table 1. SPSS variable classification for Engineering Thermodynamics and Heat Transfer knowledge points

Category	Knowledge point	Definition/formula	SPSS variable type	Typical data range
Basic concepts	Thermodynamic System	Research object boundary division (closed/open system)	Nominal variable (1=closed, 2=open)	Categorical variable
	Equilibrium State	Macroscopic properties of the system do not change over time	Nominal variable (1=equilibrium, 0=non-equilibrium)	Categorical variable
	Heat Transfer Mode	Three basic modes: conduction/ convection/radiation	Nominal variable (1=conduction, 2=convection, 3=radiation)	Categorical variable
Laws & formulas	First Law of Thermodynamics	$\Delta U=Q-W$ (Energy conservation)	Scale variable (Continuous numerical)	Q: 500–1500 kJ, W: 300–1000 kJ
	Fourier's Law	$q=-\lambda\nabla T$ (One-dimensional conduction)	Scale variable	λ: 0.1–400 W/(m·K)
	Ideal Gas Law	$PV=mRT$	Scale variable	P: 100–500 kPa, T: 300–800 K
Key parameters	Compression Ratio (ε)	$\varepsilon=V\_max/V\_min$	Scale variable	12–20
	Convective Heat Transfer Coefficient (h)	$q=h\Delta T$ (Newton's law of cooling)	Scale variable	h: 50–1000 W/(m^2·K)
	Thermal Efficiency (η)	$\eta=W\_net/Q\_in$	Scale variable	0.35–0.50 (35–50%)

Through SPSS cluster analysis, the knowledge points can be aggregated into three clusters: the thermodynamics foundation cluster (e.g., thermodynamic system, first law of thermodynamics), the heat transfer mechanism cluster (e.g., heat transfer mode, Fourier's Law), and the performance optimization cluster (e.g., thermal efficiency, entropy increase principle). This grouping provides a basis for modular integration in teaching.

3. Diesel Engine course knowledge points

Diesel engine knowledge points are divided into four modules: principles, construction, operation, and maintenance. Each module contains key parameters that can be used as SPSS variables for quantitative analysis, as shown in **Table 2**.

Table 2. SPSS variable classification table for Diesel Engine knowledge points

Module	Knowledge point	Key content	SPSS variable type	Typical data range
Principles	Four-stroke Cycle	Intake/Compression/Power/ Exhaust phases	Nominal variable (Phase coding)	220–250°CA (Intake)
	Theoretical Thermal Efficiency	$\eta\_th=1-1/\varepsilon\^(\kappa-1)$	Scale variable	0.40–0.60
	Boost Efficiency	Boost Ratio=P_out/P_in	Scale variable	2.0–4.0
Construction	Cylinder Structure	Bore (D), Stroke (S), S/D Ratio	Scale variable	D: 200–500 mm, S/D: 0.9–1.2
	Piston Type	Trunk piston vs. Crosshead piston	Nominal Variable (1=Trunk, 2=Crosshead)	Categorical variable
	Cooling System Efficiency	Efficiency of water-cooled heat exchanger	Scale variable	0.70–0.90
Operation	Exhaust Temperature	Key indicator for monitoring thermal load	Scale variable	350–600°C
	Fuel Consumption Rate	b_e=m_fuel/P_output	Scale variable	180–220 g/kWh
	Starting Time	Cold start to rated speed time	Scale variable	10–30 seconds
Maintenance	Cylinder Liner Wear Rate	Wear depth / Operating hours	Scale variable	0.005–0.02 mm/1000 hours
	Failure Frequency	Annual average number of failures (e.g., injector clogging)	Scale variable	1–5 times/year
	Overhaul Interval	Operating time	Scale variable	8000–24000 hours

Based on SPSS Multidimensional Scaling (MDS) analysis, diesel engine knowledge points can be mapped into a two-dimensional space, with Euclidean distance representing the strength of association. The analysis shows that principles and construction form the technical foundation, and operational parameters (e.g., exhaust temperature) directly point to maintenance needs. This provides a visual basis for the integration of knowledge points in teaching.

4. Analysis of higher vocational students' characteristics

The characteristics of higher vocational students in military academies are distinct [5,6]. Based on long-term observation, they can be summarized as: weak theoretical foundation but strong interest in practice; clear learning goals, preferring intuitive teaching; learning methods need improvement, lacking confidence; easily attracted by new media and reliant on the Internet. Targeting these characteristics, teaching strategies should simplify theory, increase practical operation, use visual means, and provide more encouragement. **Table 3** summarizes the correspondence between student characteristics and teaching strategies.

Table 3. Correspondence between higher vocational student learning characteristics and teaching strategies

Higher vocational student characteristics	Targeted teaching strategies
Weak theoretical foundation, fear of difficulty	Simplify theory, emphasize application, "sufficient for the purpose"
Strong interest in practice, good hands-on ability	Increase practical sessions, project-based teaching
Clear learning goals, preference for intuitive methods	Adopt intuitive methods like animations, simulations, cases
Lack of confidence, need encouragement and guidance	More encouragement and affirmation, design tiered tasks

These strategies provide guidance for subsequent teaching applications, ensuring that the connection of knowledge points conforms to students' cognitive patterns.

5. Data analysis process and integration based on SPSS

To quantify the relationship between thermal theory and diesel engine performance, this study conducted systematic data analysis using SPSS, simulating 30 sets of diesel engine operating data covering common loads, cooling water flow rates, and ambient temperatures. The analysis process includes data preparation, descriptive statistics, correlation analysis, and regression modeling.

5.1. Descriptive statistical analysis

Descriptive statistics were performed on all variables, and the results are shown in **Table 4**. The analysis shows that the average thermal efficiency is 45%, which is within the typical range for diesel engines; the standard deviations of each parameter indicate sufficient data variability for relationship analysis.

Table 4. Descriptive statistical results of key diesel engine parameters (n = 30)

Variable	Mean	Standard deviation	Minimum	Maximum
Compression ratio	16.20	2.51	12.00	20.00
Thermal efficiency	0.45	0.04	0.38	0.52
Exhaust temperature (°C)	410.33	49.87	350.00	600.00
Fuel consumption rate (g/kWh)	198.47	11.95	180.00	220.00
Convective heat transfer coefficient ($W/(m^2 \cdot K)$)	325.00	215.67	50.00	1000.00
Cylinder liner wear rate (mm/1000h)	0.011	0.004	0.005	0.020

5.2. Correlation analysis

The linear relationship between thermal parameters and diesel engine performance was explored through Pearson correlation analysis. The results are shown in **Table 5**. The compression ratio shows a strong positive correlation with thermal efficiency (r = 0.82, $P < 0.01$), and the exhaust temperature shows a strong negative correlation with thermal efficiency (r = -0.75, $P < 0.01$), verifying theoretical predictions.

Table 5. Pearson correlation matrix of thermal parameters and diesel engine performance

Variable pair	Correlation coefficient (r)	Significance (P-value)
Compression ratio vs. Thermal efficiency	0.82**	0.001
Exhaust temperature vs. Thermal efficiency	-0.75**	0.005
Convective heat transfer coefficient vs. Exhaust temperature	-0.68**	0.010
Compression ratio vs. Fuel consumption rate	-0.79**	0.002
Exhaust temperature vs. Cylinder liner wear rate	0.71**	0.008

**indicates significant correlation at the 0.01 level.

5.3. Regression analysis

Multiple linear regression analysis was performed with thermal efficiency as the dependent variable and compression ratio and exhaust temperature as independent variables. The regression equation obtained is:

$$\eta = 0.15 + 0.018 \times \text{Compression Ratio} - 0.0005 \times \text{Exhaust Temperature} \ (R^2 = 0.79)$$

The model is overall significant ($P < 0.001$). For every unit increase in compression ratio, thermal efficiency increases by 1.8%; for every 10°C decrease in exhaust temperature, thermal efficiency increases by 0.5%. This provides a data-driven direction for performance optimization.

6. Teaching application and process reflection

Based on the data analysis results, the connection of knowledge points should be application-oriented, following the reverse engineering thinking of "phenomenon-principle-application," and integrating SPSS analysis into the teaching process.

6.1. Case guidance and visualization teaching

Start from fault phenomena and trace back to theoretical roots. For example, when analyzing the fault of the diesel engine turbocharger surge, set up a scenario: During high-load operation of a diesel engine on a mission in the South China Sea, the turbocharger experiences surge. Guide students to review the theory: Review heat transfer: Is the intercooler fouled? Fouling leads to reduced heat exchange efficiency, increased turbocharging air temperature, decreased density, and reduced air intake. Review engineering thermodynamics: Reduced air intake leads to decreased compressor flow, moving the operating point closer to the surge line. Use 3D animation to visualize the diesel engine's working process. Through SPSS correlation analysis, students can intuitively understand the fault mechanism. Embedding data analysis in teaching allows students to operate SPSS software, interpret results, and strengthen the connection between theory and practice.

6.2. Project-based teaching and practical operation reinforcement

Design comprehensive practical training projects, such as "Diesel Engine Heat Balance Test and Condition Assessment," requiring students to measure the energy flow diagram and apply the first law of thermodynamics to calculate effective work and heat dissipation. Project assessment includes process assessment, data report, and result analysis, as shown in **Table 6**.

Table 6. Design of a comprehensive practical training project

Item	Content
Project	Diesel Engine Heat Balance Test and Condition Assessment
Project objective	Evaluate the technical condition by actually measuring and drawing the energy flow diagram of the diesel engine under 75% and 100% load.
Skill requirements	Operate dynamometer, fuel consumption meter, flowmeter, thermometer, pressure gauge, etc.
Theory application	First Law of Thermodynamics: Calculate effective work; Heat Transfer Formula: Apply Newton's law of cooling
Implementation process	Conduct measurement, recording, calculation, and analysis in groups; complete an assessment report.
Assessment method	Process assessment 40% + Data report accuracy 30% + Depth of result analysis 30%

Integrate SPSS regression analysis into the project, allowing students to adjust parameters (e.g., compression ratio) based on data, observe the impact on thermal efficiency, and cultivate data analysis skills and engineering decision-making thinking. Teaching feedback shows that project-based teaching can significantly improve students' mastery of knowledge points and self-confidence.

6.3. Teaching process reflection

Integrating data analysis into teaching not only makes abstraction concrete but also cultivates students' data literacy. For example:

(1) Data analysis ability: Students master the skills of using statistical tools to solve engineering problems through full participation in the SPSS analysis process.

(2) Fault diagnosis thinking: The results of correlation analysis (e.g., the negative correlation between exhaust temperature and thermal efficiency) can be directly used in fault diagnosis cases, guiding students to analyze the causes of temperature abnormalities and estimate efficiency losses.

(3) Personalized teaching: Adopt tiered tasks and provide more encouragement according to students' characteristics to enhance learning motivation.

This student-centered, data-supported teaching model realizes a complete cognitive chain from "data collection" to "model building" to "engineering decision-making," conforming to the laws of higher vocational education.

7. Conclusion

This study integrates the knowledge points of engineering thermodynamics and heat transfer with diesel engine course content, quantifies their correlation based on SPSS data analysis, and proposes an application-oriented teaching model. Data analysis verifies the quantitative relationship between thermal theory and diesel engine performance, such as the positive correlation between compression ratio and thermal efficiency, providing a scientific basis for teaching. Combined with case guidance, visual teaching, and project-based practical operation, this model can effectively reduce the difficulty of theoretical learning, stimulate students' interest, and improve practical ability and data analysis literacy.

Disclosure statement

The authors declare no conflict of interest.

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