Exploration of the "Three-Spectrum Integration" Teaching Reform Path for Graduation Design in Mechanical Engineering Major

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Abstract. To systematically address the prominent issues such as fragmented knowledge, implicit ability cultivation, and superficial ideological and political education in mechanical engineering graduation design, this study innovatively constructed and applied a teaching reform model that deeply integrates knowledge graphs, ability graphs, and ideological and political graphs. By constructing structured multi-level knowledge graphs, it broke down the barriers between "theory - design - standards"; designed explicit ability graphs to guide and quantitatively evaluate the entire process of solving complex engineering problems; and created naturalized ideological and political mapping graphs to organically integrate value guidance into the entire graduation design process. The practical results show that this model effectively improves the graduation design performance, promotes the systematic knowledge construction and comprehensive ability development of students, and realizes the refined management of the teaching process and the scientific transformation of the evaluation system, providing an effective path for cultivating high-quality mechanical engineering talents in the new era.

Keywords: Knowledge graph; Ability graph; Ideological and political education in courses; Graduation design; Mechanical engineering; Teaching reform

1 Introduction

The knowledge graph in the field of education includes the organizational representation of knowledge, resources, learning activities, etc. in the field of education. As the core and carrier of education, courses are the cornerstone of the construction of educational knowledge graphs [1]. Graduation design is an important practical link in higher engineering education and a key step for students to comprehensively apply professional knowledge and complete the transition from theory to engineering practice[2], Knowledge graphs, as an important method for summarizing the development trends of disciplines, revealing knowledge structures, and exploring the directions of scientific and technological innovation, provide new ideas for solving difficult problems [3,4]. This study aims to explore the comprehensive application of knowledge graph, ability graph,

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and ideological and political graph in mechanical engineering graduation design. By constructing a multi-level graph system, the teaching process and evaluation mechanism are reshaped to improve the quality of graduation design and the effectiveness of talent cultivation.

1.1 Existing Issues in Mechanical Engineering Graduation Design

Based on the questionnaires and discussions with students and front-line teachers, the following main problems existing in the process of graduation design have been identified. The specific results are shown in Table 1.

Table 1. Results of the Questionnaire on the Existing Problems of Graduation Design

Option	Subtotal	Proportion
Disconnection of knowledge association	71	61.74%
Ineffective guidance and evaluation	49	42.61%
Forced integration of ideological and political education in courses	43	37.39%
Difficulties in ability transformation	38	33.04%
Other issues	16	13.91%

(1)Knowledge Association Breakdown.

Students find it difficult to effectively apply knowledge from prerequisite courses such as mechanical principles to design tasks[5]; When facing interdisciplinary issues such as intelligent manufacturing, it is also impossible to systematically integrate multiple fields such as mechanics, control, and sensing.

(2)The challenge of transforming "knowledge fragments" into "systemic capabilities"

There are issues of ambiguity and fragmentation in the current graduation design process regarding ability development. The goals of "innovation ability" and "engineering practice ability" in the training program are too abstract.

(3)The challenge of transforming "knowledge fragments" into "systemic capabilities"

There is a common phenomenon of "hard integration" in graduation projects, where some teachers rigidly require students to use vocabulary such as "great country craftsmanship spirit" and "science and technology serving the country", resulting in abrupt content; Many guidance teachers only focus on technical implementation, ignoring the rich ideological and political elements inherent in engineering practice.

(4)Inefficient guidance and evaluation

In the guidance process, due to the lack of a knowledge graph that links students' knowledge gaps with learning resources, teachers find it difficult to accurately locate problems; In the evaluation process, due to the lack of quantitative correlation between

achievements and core knowledge nodes, the evaluation system lacks objective and scientific basis.

2 Teaching Reform Measures for Graduation Design of Mechanical Engineering Major

2.1 Building a Multi-level Knowledge Graph and Connecting Knowledge Associations

A systematic collection and organization of core knowledge in the field of mechanical engineering was carried out for the graduation project of the mechanical engineering major, focusing on the phenomenon of "knowledge association fracture and design process no need". Then, with the help of the Rain Classroom platform, a knowledge graph of the third level knowledge of mechanical engineering graduation design was constructed, as shown in Figure 1. This diagram clearly presents the process framework of graduation design, with systematicity and operability, which can provide clear ideas and reference standards for mechanical engineering graduation design, and help improve design quality and students' comprehensive abilities.

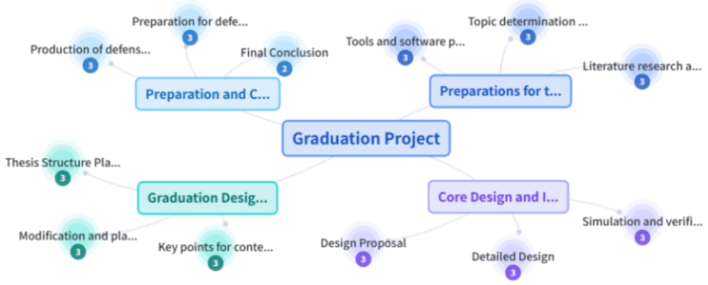
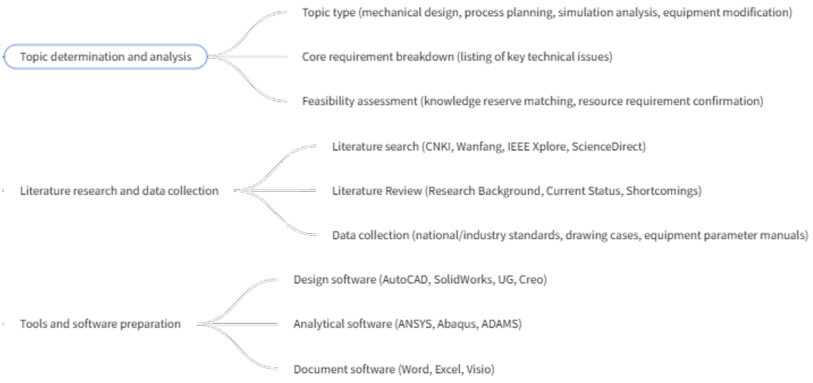
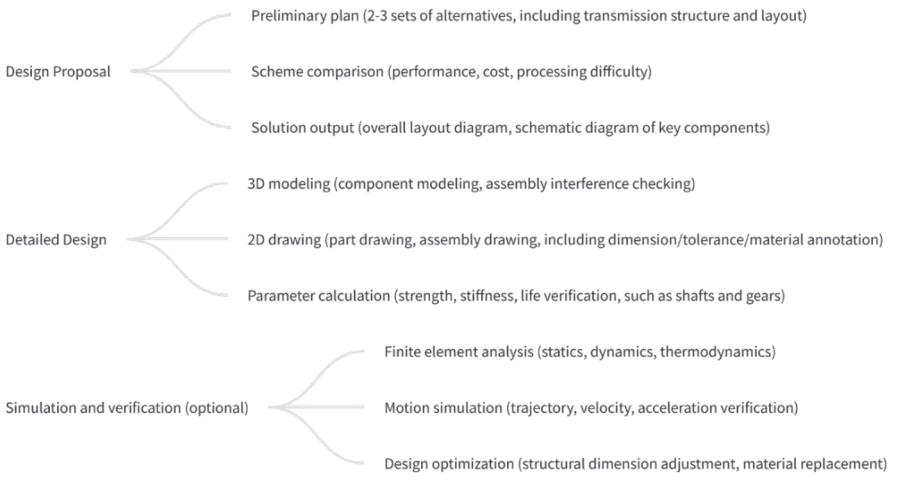


Fig. 1. Third level knowledge graph

The specific content under the fourth level nodes in the knowledge graph is shown in Fig. 2. For specific details, please refer to the fig.(a), (b), (c)and(d).

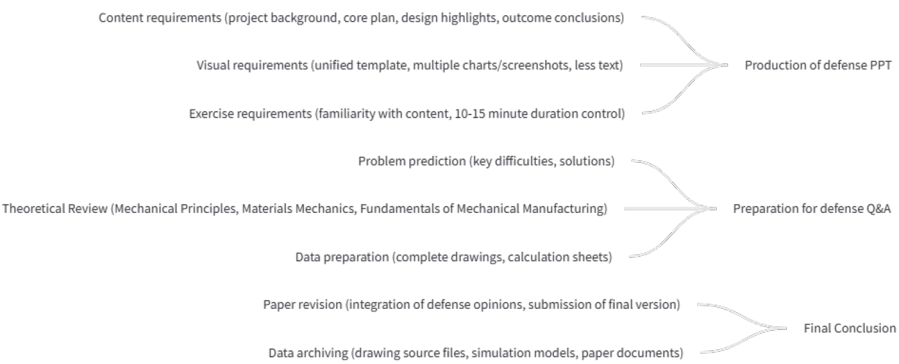


(a) Preparations for the Graduation Project



(b) Core Design and Implementation Stage

(c) Graduation Design Document Writing



(d) Preparation and conclusion of the defense specific content

Fig. 2. Specific content under level 4 nodes

2.2 Constructing a Mechanical Engineering Capability Map for Graduation Design

The top-level goal of the graduation design ability map for mechanical engineering majors is the ability to solve complex engineering problems, which is then decomposed into several core goals layer by layer. This article makes implicit ability requirements explicit, abstract ability goals concrete, and discrete ability training systematic. We have established a three-level capability system of "basic ability professional ability comprehensive ability" to support the solution of complex engineering problems. The specific capability levels, dimensions, and requirements are shown in Table 2.

Table 2. Capability Levels, Dimensions, and Requirements

Ability level	capability dimension	Specific ability requirements
Basic Capabilities	Drawing and Expression	Proficient in using CAD software to draw engineering drawings that comply with national standards and specifications.
	mechanical analysis	Complete mechanical structural statics/dynamics analysis to ensure design reliability.
professional competence	Innovative Design	Propose optimization solutions and verify their feasibility through simulation.
	Process Planning	Develop a manufacturing process roadmap, considering material selection and cost control.
	project management	Coordinate design progress, coordinate team resources, and achieve phased goals.
comprehensive ability	Interdisciplinary integration	Integrate knowledge from disciplines such as electrical engineering and control to achieve mechatronics design.
	Engineering Ethics Decision making	Evaluate the impact of design on the environment and safety, and propose sustainable solutions.

The competency map constructed based on the competency points and content in Table 2 is shown in Figure 3.

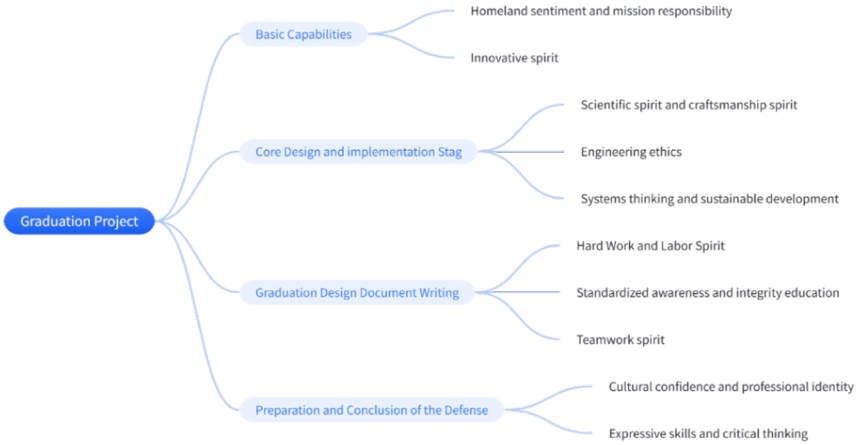


Fig. 3. Capability map

At the start of the graduation project, a clear competency map is distributed to every student and mentor, making it a shared 'action roadmap' for both teachers and students. Based on the chart, the guiding teacher should not only check the progress during the opening and mid-term inspections, but also consciously ask questions and guide students to assess their mastery of corresponding ability points.

2.3 Constructing a 'Graduation Design Course Ideological and Political Mapping Map' to Achieve Seamless Integration Like 'Salt in Water'

Explore the inherent ideological and political genes throughout the entire process of graduation design, and integrate value shaping into the entire process of knowledge transmission and ability cultivation. Map the key process nodes of the graduation project naturally with possible ideological and political connotations. The ideological and political dimensions and mapping points constructed at different stages are shown in Table 3.

Table 3. Dimensions and Mapping Points of Ideological and Political Education in Various Stages of Graduation Design

Graduation Design Stage	Dimensions and Mapping Points of Ideological and Political Education
Preparations for the Graduation Project	**Homeland sentiment and mission responsibility:** Guide the topic selection towards major national needs, regional economic development, and people's livelihood improvement. **Innovative spirit:** Encourage challenging cutting-edge and interdisciplinary topics, and cultivate a sense of daring to be the first.
Core Design and implementation Stag	**Scientific spirit and craftsmanship spirit:** emphasizing sufficient theoretical basis, rigorous calculation, and authentic data **Engineering ethics:** guiding thinking about the social impact of technology, conducting risk assessments, and making ethical decisions. **Systems thinking and sustainable development:** require a comparison of multiple technical and economic options, considering full lifecycle costs, resource consumption, and recyclability.
Graduation Design Document Writing	**Hard Work and Labor Spirit:** Cultivate the qualities of perseverance and pursuit of truth when facing experimental failures and debugging setbacks. **Standardized awareness and integrity education:** Strictly abide by academic norms, experimental operating procedures, intellectual property regulations, and eliminate plagiarism and data falsification. **Teamwork spirit:** In projects that require collaboration, clarify division of labor and responsibilities, and cultivate communication and collaboration skills.
Preparation and Conclusion of the Defense	**Cultural confidence and professional identity:** When summarizing achievements, guide students to see the progress of China's manufacturing industry and the value of their own profession, and enhance their sense of professional pride. **Expressive skills and critical thinking:** Clear statements, rigorous logic, facing doubts calmly, cultivating a rigorous academic attitude.

2.4 Optimize Guidance and Evaluation, Strengthen Teaching Effectiveness

In this educational reform, the graduation project score will be calculated as the score of the topic proposal stage (10%) + the mid-term review stage (10%) + the review stage score (20%) + the mutual evaluation stage score (20%) + the defense stage score (40%). At different stages, teachers will push different learning tasks and tests in real time through the knowledge graph, and then students will be evaluated for their knowledge shortcomings through the question test section in the knowledge graph. Teachers can formulate targeted guidance plans and effectively avoid the problem of some students completing their graduation projects in the final stage in a concentrated manner, resulting in low quality.

3 Implementation Effect

3.1 Improved Design Quality and Process

After the educational reform, there are five evaluation indicators for the curriculum objectives, and the actual score of each student is S_i (i=1,2,... n), and the corresponding full marks or standards are T_i (i=1,2,... n). Then the degree of achievement D_i of this student in the course objectives can be expressed as:

$$D_i = \frac{\sum(\frac{S_i}{n} * W_i)}{T_i} \times 100\% \quad (1)$$

Here, W_i represents the weight of each evaluation index.

The graduation grades and the achievement of course objectives of the 2025 graduating class are shown in Table 4. Compared with the target achievement rate of 69.4% for the 2024 graduating class, it has increased by 5.6%. Moreover, based on the five-level grading system of our school, after the educational reform, the overall grades have been improved from "average" for the 2024 graduating class to "good" for the 2025 graduating class.

Table 4. Degree of Goal Achievement

Composition of grades	Average grade	Weight	Degree of goal achievement
Proposal Report	76	0.1	
Mid-term inspection	80	0.1	
Guidance on grades	70.5	0.2	D_i=75%
Review the results	73.8	0.2	
Defense score	74.5	0.4	

In conclusion, under the guidance of knowledge graphs and ability graphs, the topics of graduation projects are more cutting-edge and the process is more systematic and standardized. Students can effectively integrate knowledge to achieve high-level goals, thereby significantly enhancing the technical depth, innovation and comprehensiveness of the final results.

3.2 Promoted Students' Abilities and Literacy

The 'three spectra' enable students to have a clear understanding of their learning goals, shifting from passive to active. This not only strengthens their ability to integrate and transfer knowledge, but also internalizes ideological and political elements such as craftsmanship and engineering ethics, while simultaneously shaping their professional values and comprehensive abilities.

3.3 Optimized Teaching Management and Evaluation

Guidance teachers can achieve paperless office based on the "three spectra", thereby achieving accurate diagnosis and efficient guidance throughout the entire graduation process. At the same time, the evaluation system has shifted from relying solely on drawings, papers, and other evaluations to being based on multidimensional quantitative standards, achieving a scientific assessment of the entire process of knowledge, ability, and ideological and political education.

4 Summary

This article proposes a teaching reform plan that integrates knowledge graph, ability graph, and ideological and political education graph to address the problems of scattered knowledge, implicit ability cultivation, and rigid ideological and political education in mechanical engineering graduation design. By constructing knowledge graph to connect knowledge associations, using a capability graph to achieve process oriented guidance and evaluation, and utilizing an ideological and political mapping graph to achieve seamless integration of value guidance. Practice has shown that this model effectively improves graduation design scores, making students' learning paths clearer and their ability development more systematic. At the same time, it promotes the refinement of process management and the scientific evaluation system, providing an effective path for cultivating compound innovative talents.

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Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

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