A professional course design approach for the integrated Vocational-Bachelor cultivation mode based on knowledge graphs within the STEM framework

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Abstract. The integrated vocational-bachelor cultivation mode is an effective means of achieving mass higher education, under which, students complete associate education at one vocational college, then transfer to another university after passing a transition examination to continue with bachelor's degree courses, ultimately obtaining a bachelor's degree. Due to the different focuses of vocational education and undergraduate education, the coherence between the two educational stages has a significant impact on the implementation effectiveness of this cultivation mode. To enhance the coherence between these two educational stages, this paper proposes a method for designing professional courses based on knowledge graphs within the STEM framework. The principles of STEM education serve as the guiding thread for designing professional courses at both educational stages. To ensure that STEM education concepts are implemented in professional course objectives, content, teaching activities, and course assessments, so as to enhance students' interdisciplinary problem-solving abilities, a dynamic mechanism for constructing, updating, and mapping knowledge and ability graphs is constructed. Both the knowledge and ability graphs are tagged with S, T, E, and M labels. These labels would be used by teachers to assess whether the courses effectively incorporate STEM teaching principles. After completing their course tasks, students receive corresponding ability tags, allowing them to adjust their learning focus based on their tag distribution. To stimulate students' enthusiasm for interdisciplinary learning, a reward system is designed to encourage feedback on knowledge elements within the knowledge graph during the teaching process, continuously improving both graphs. This research could provide a reference for integrated education.

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1 Introduction

The integrated Vocational-Bachelor cultivation mode is an important direction for vocational education reform. Through this integrated mode, students can directly enter the bachelor's degree stage after completing their vocational education courses without having to repeat knowledge they have already mastered, thereby saving time and costs[1]. This mode not only improves the efficiency of educational resource utilization but also better meets society's demand for high-quality technical and skilled talents. Additionally, the integrated education mode encourages cooperation between vocational colleges and regular universities, promoting the sharing of educational resources and advancing the integration and development of vocational education and general higher education[2].

However, the integrated vocational-bachelor cultivation mode is a complex systemic project involving two independent educational entities: vocational colleges and regular undergraduate universities. During implementation, talent cultivation is often carried out in segments, leading to inherent differences in course standards, teaching objectives, curriculum delivery, and academic assessment between the two entities[3]. This results in an inability to truly achieve seamless education across different stages. After transferring to the undergraduate level, students often find it challenging to grasp theoretical knowledge, and they may lose the distinctive features of vocational education after graduation, making them less competitive in the job market. Therefore, the continuity of integration between vocational and bachelor's degrees has received widespread attention from scholars [4-6]. The professional courses are a critical issue that needs urgent resolution to enhance the connection between the two educational stages. Based on the concept of occupational job capabilities, Song[7] proposes that the cultivation of talents through a three-plus-two segmented program between junior college and bachelor's degree should focus on course integration as the key entry point, and design for course integration. Wang et al.[8] designed a curriculum of emergent and critical care for nursing students upgraded from junior college through bedside teaching is practical and operational, and it could be used as reference for other subjects in nursing students upgraded from junior college. However, existing studies mostly rely on specific examples, showcasing particular course designs, but have yet to summarize a set of guidelines specifically for professional courses that integrate junior college and bachelor's programs. Thus, a new method for designing professional courses aimed at genuinely leveraging the advantages of extended education is proposed by this research.

The STEM education concept, which integrates S (Science), T (Technology), E (Engineering), and M (Mathematics), provides a new paradigm for cultivating interdisciplinary talents. With the rapid development of technology and the increasing demand for composite talents from society, the importance of STEM education has become increasingly prominent, making it one of the key directions of global educational reform[9]. Hennessey and Freeman[10] produced a nationally endorsed set of lesson-level Learn Objects for a year-long introductory biology for major's course in STEM. by which instructors can implement backward course design with daily and weekly learning activities and with formative and summative assessments. Plumley et al.[11] developed co-redesign methods in partnership with disciplinary experts to create high-structure STEM courses that better support students and produce informative digital event data. However, there has been no research applying STEM education concepts to the design of professional courses for integrated Vocational-Bachelor cultivation mode. To ensure that STEM education concepts are implemented in professional course objectives, content, teaching activities, and course assessments, so as to enhance students' interdisciplinary problem-solving abilities, a dynamic mechanism for constructing, updating and mapping knowledge and ability graphs is constructed. The main framework of this research is shown in Fig.1.

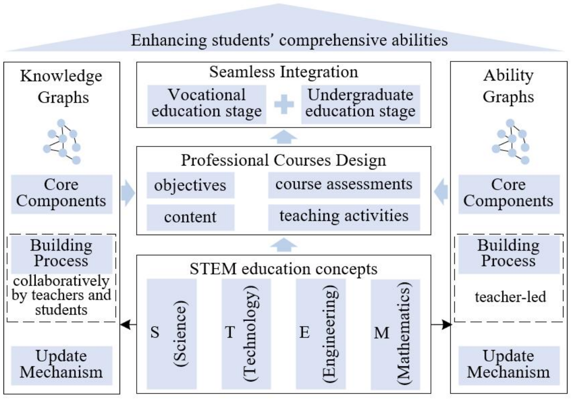

Fig. 1. The main framework of the research.

2 Analysis of pain points in the professional course design under the integrated vocational-bachelor cultivation mode

2.1 The disconnection of course objectives

Vocational education focuses on technical skills and applications, oriented towards job competency. Undergraduate education emphasizes system design optimization, stressing the systematic nature of theoretical knowledge and the cultivation of transferable skills. However, there is a lack of gradual transition between the two education stages, making it difficult for students to adapt to undergraduate-level theoretical knowledge after entering the undergraduate stage, and they may lose the distinctive features of vocational education, resulting in insufficient job competitiveness. For example, logistics major students can proficiently operate WMS and TMS systems at the vocational education stage, but after advancing to undergraduate studies, they struggle to optimize inventory strategies and vehicle dispatching strategies through mathematical modelling.

To address this issue, this paper inserts an intermediary layer into the ability map and the knowledge map, identifies gaps in abilities and knowledge between the specialized and undergraduate levels, adds bridging abilities and knowledge elements, and designs corresponding bridging courses. For instance, in the final semester of the specialized program, a course titled 'Fundamentals of Logistics Data Analysis' is added as a transitional course between the specialized courses 'Warehouse Management Practices'/ 'Transportation and Distribution' and the undergraduate courses 'Smart Warehouse Optimization'/ 'Transportation Engineering'.

2.2 Course content repetition

Inconsistent curriculum standards lead to repetitive content, resulting in wasted class hours and resource depletion. Course content repetition exists across different educational stages and courses, primarily manifested as overlapping and discontinuous teaching content, with insufficient integration of curriculum standards, content, and teaching activities. In the undergraduate stage, skills taught in the vocational educational level are repeated. Take the logistics major for example, WMS operation has been taught at t the vocational educational level, but system login in is still repeated taught in the undergraduate stage. Similar repetition occurs between different courses. For example, the 'Smart Warehouse Management' course includes site selection methods, which are also covered in the 'Logistics System Planning and Design' course. The RFID technology principles often appear in 'Smart Warehouse Management' course, 'Internet of Things' and 'Smart Logistics Systems' courses.

To address this issue, a curriculum design based on knowledge graphs and ability graphs is proposed. For courses across different educational stages and subjects, shared knowledge elements in the knowledge graph will be analysed to identify repetitive content. When the similarity of knowledge elements between two-stage courses exceeds 35%, an automatic duplicate audit alert is triggered, requiring manual confirmation whether to retain the content. Key layers of ability progression in the knowledge graph will also be constructed to indicate the deepening of the same ability. For instance, students can learn 'inventory counting operations' at the junior college level and progress to 'inventory data analyses' at the undergraduate level.

2.3 The evaluation system is fragmented

Vocational education over emphasizes the assessment of operational proficiency while neglecting the understanding of underlying principles, leading to biased evaluations. For example, during the vocational education phase, there is an excessive focus on the proficiency of forklift driving, while the understanding of hydraulic systems, braking systems, and other fundamental principles is overlooked. The main issue with undergraduate evaluations is that they are overly abstract, focusing solely on the outcome-based assessment of theoretical knowledge and ignoring practical skills. As a result, some vocational students may score high due to their practical skills and advance to undergraduate studies, but they struggle due to weak theoretical foundations, significantly affecting their learning outcomes.

To address this, this paper proposes dynamically generating ability radar charts for each student as the teaching process progresses. These radar charts compare individual four-dimensional labels against job position requirements, providing feedback to optimize course design. Additionally, ability elements are linked to evaluation scenarios. For instance, the ability element 'warehouse location capability-M' is associated with the evaluation scenario 'selecting a warehouse location for a company to reduce delivery costs by at least 8%'.

3 A knowledge graph construction plan within the STEM framework

3.1 The core components of graphs

Knowledge graphs and ability graphs are both composed of nodes and connections. Nodes represent knowledge units or ability units, each having a name and attributes, while connections indicate the relationships between the nodes. The connections between knowledge units or ability units can be further divided into representational content relationships and function-oriented relationships (shown in Table 1).

Table1. The elements of knowledge unit and ability unit

Element		Knowledge Unit	Ability Unit
Category		Concept; Principle; Technology; Tool.	Cognitive; Operational; Design; Evaluation.
Attributes		STEM tag; Difficulty level; Prerequisite course;Links to teaching resource.	STEM tag; Skill levels; Related knowledge elements; Evaluation criteria
Connections	Contents	Hierarchical; Logical; Interdisciplinary.	Advanced; Collaborate; Transform
	Function	Vertical progression, Horizontal integration, Dependency constraints.	Transformation, collaboration, feedback.

The *STEM tag* can unify the knowledge and skill standards of vocational education which is skills-oriented with those of undergraduate education which is innovation-oriented, so as to avoid gaps.

The coherence between vocational and bachelor's cultivation mode can be reflected in the connection.

For example, one type of *hierarchical* relationship is the transition from vocational education to a bachelor's degree. *Advanced* relationship could response skills progress from skills to analysis.

3.2 The building process of graphs

3.2.1 The process of building knowledge graphs

The process of building knowledge graphs is teacher-led, and details are as follows:

(1) Objective Decomposition. Taking logistics management courses as an example, the objective '*reduce warehousing costs by 20%*' is broken down into sub-objectives such as '*demand forecasting*', '*inventory optimization*', and '*technology application*'.

(2) Problem-Oriented Approach. Reverse-engineer knowledge elements from real problems. For example, '*How to handle supply chain disruptions?*' requires '*safety stock models* (*S/M*)' and '*emergency dispatch agreements* (*E*)'.

(3) Cross-Disciplinary Mapping. During the vocational education stage. Focus on T/E labels such as 'warehouse equipment operation' and 'layout design', with knowledge elements primarily operational. During undergraduate stage, S/M labels such as 'probabilistic foundations of inventory models' and 'optimization algorithms' will be deepened, with knowledge elements emphasizing theoretical aspects.

(4) Industry Calibration. Incorporate feedback from enterprises, such as trends in smart warehousing technology, to dynamically supplement knowledge elements, such as 'drone inventory technology' with T tag.

3.2.2 The process of building ability graphs

The process of building knowledge graphs is completed collaboratively by teachers and students, with detailed steps as follows:

(1) Bloom's Taxonomy Anchoring. Select the level that matches your profession from the six tiers ranging from 'remembering' to 'creating'.

(2) Task Backward Design. Design typical tasks such as 'Design a low-carbon warehouse plan', and break it down into sub-skills, which composed of data analysis (M label), technology selection (T label) and engineering drawing (E label).

(3) Student Feedback Adjustment: Based on the distribution of skill labels (e.g., students generally lack S labels), supplement corresponding skill training (e.g., add tasks like 'Scientific Principle Analysis').

3.3 The dynamic update mechanism of graphs

The graph is non-static and requires continuous iteration. The updates will be driven by teacher and student's feedback during the teaching process. As for teachers, they will add new nodes based on industry trends, such as the application of AI in logistics. For students, they will report knowledge gaps or errors through a reward system, which are automatically mapped to S/T/E/M labels and integrated into the graph. This mechanism solves the long-standing problem of knowledge lag in the vertical integration of vocational and undergraduate education, ensuring the timeliness and relevance of the graph.

To stimulate interdisciplinary learning enthusiasm, the system sets up a multi-level reward mechanism. Basic feedback such as pointing out errors in the graph, earns small rewards. Innovative contributions such as proposing new knowledge elements, earn large rewards. This not only improves the quality of the graph but also cultivates students' critical thinking skills. Teachers can also identify course weaknesses through tag analysis.

After students complete tasks, the system automatically assigns corresponding label ability labels. For example, after completing an inventory optimization report, the students will earn E and M labels. These labels form an individual's capability profile, which students can use to adjust their learning focus. If a student's label distribution shows weakness in the S label, the system recommends supplementing with courses on scientific principles, and this will enhance autonomous learning motivation. At the same time, labels serve as certificates of competence, facilitating the display of interdisciplinary skills during college applications or job searches. For example, logistics positions preferring E/T label capabilities.

4 Conclusions

The main content of the text describes the use of knowledge maps and ability maps modelled under the STEM framework for designing major courses during integrated undergraduate and postgraduate education. These maps visually display the structure and relationships of course knowledge and abilities. The knowledge map not only shows the logical connections between different knowledge points but also uses hierarchical structures to help students intuitively understand complex concepts. The ability map lists specific requirements and application scenarios for each skill in detail, using case analysis and case studies to enable students to master key abilities through practical operations. A dynamic tagging system updates students' learning progress and mastery in real-time, allowing teachers to adjust teaching strategies promptly based on feedback mechanisms to ensure that every student keeps up with the learning pace. Cross-stage mapping clearly demonstrates the transition path from introductory to advanced courses through charts and timelines, helping students clarify their learning goals and directions. The advantage of this professional course design method lies in effectively solving issues related to course transitions and enhancing students' comprehensive abilities through interdisciplinary training. The main contributions of this article are as follows:

(1) Integrate STEM education concepts and knowledge graph technology to achieve intelligent reorganization and personalized recommendation of course content, providing customized learning paths for each student.

(2) A dynamic mechanism for constructing, updating, and mapping knowledge and ability graphs is constructed. The graphs developed during the design, teaching, and evaluation of professional courses provides specific support and assurance for the implementation of STEM.

Future research will be conducted from two aspects. First, ontological languages will be used to express knowledge graphs and ability graphs, facilitating the structuring of graph data to provide data support for subsequent use and analysis in the integrated training of junior college and undergraduate programs. Second, more cases of integrated junior college and undergraduate training will be surveyed to further analyze issues in professional course design and teaching processes, thereby providing decision-making support for corresponding measures.

This study was supported by Research Project on Teaching Reform in Vocational Education in Shandong Province (2024345:Research on Talent Cultivation Model for Logistics Management Specialization Bridging Junior College and Bachelor's Degrees: Dual Drivers, Triple Integration, and Quadruple Synergy), Shandong Province Undergraduate Teaching Reform Research Project (Z2022028: Research and Practice on the Collaborative Talent Cultivation System of 'Four Chains Integration, Five-in-One, and Multi-party Synergy' for Smart Logistics Industry College; M2024198:Exploring and practicing the cultivation of composite applied logistics talents at local universities under the perspective of new quality productivity, focusing on the integration of plumbing technology, theory and practice, and multi-dimensional collaboration).

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