

Research on Dynamic Mapping and Collaborative Optimization of Engineering Practice Projects and Curriculum Knowledge Points Based on OBE Philosophy

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Abstract:

With the deepening of engineering education reform, the disconnection between theoretical instruction and engineering practice in talent cultivation programs has become increasingly prominent. Conventional curriculum revision models, which largely rely on the subjective experience of experts, often fail to precisely address the rapidly evolving technical requirements of the industry. To address this challenge, this paper proposes a dynamic mapping model for curriculum and practice based on the Outcome-Based Education (OBE) philosophy. By structurally organizing the curriculum knowledge system and reconstructing engineering tasks into standardized expressions with theoretical attribution, this model utilizes semantic vectorization technology to achieve automated alignment between engineering task requirements and the curriculum knowledge system. This study aims to establish a feedback loop through quantitative analysis of alignment degree, thereby providing objective data support for decision-making regarding the addition or removal of curriculum content. This approach establishes a viable theoretical architecture for bridging the semantic gap between engineering descriptions and theoretical definitions, offering an objective decision-making reference for the dynamic adjustment of engineering-oriented talent cultivation programs.

Keywords:

Outcome-Based Education (OBE), Semantic Alignment, Project-Based Learning (PBL), Knowledge Mapping

1. Introduction

1.1. Research Background

Modern engineering education highly advocates the Outcome-Based Education (OBE) philosophy, which drives instructional design through clearly defined expected learning outcomes [1], aiming to fundamentally enhance the quality of talent cultivation. Within this context, Project-Based Learning (PBL) serves as a critical pedagogical vehicle for achieving the core objectives of OBE [2], effectively

strengthening students' ability to solve practical problems by situating them in the realistic context of complex engineering challenges. However, the curriculum design in most professional training programs often exhibits a lag, making it difficult to respond rapidly to the industry's demand for emerging knowledge points. Consequently, how to achieve dynamic adjustments to training programs while ensuring pedagogical compliance has become a focal issue in the reform of project-based higher education.

1.2. Core Pain Points

The course syllabus exists as an abstract description of theoretical knowledge, whereas engineering projects consist of system architectures or concrete implementation steps; the lack of a unified semantic metric between the two creates a “semantic gap” between curriculum and projects. There is a lack of feedback mechanisms for the revision of talent cultivation programs. Most modifications to these programs rely on the subjective experience of experts, lacking quantitative analytical evidence supported by engineering practice data. Furthermore, the mapping between courses and projects is complex. The relationship between courses and projects is typically a many-to-many mapping, and relying on manual maintenance leads to information distortion.

2. Related Work

In response to the challenges of the “semantic gap” between curriculum and projects and the lack of quantitative feedback raised in the introduction, academic circles have conducted relevant explorations. This study is grounded in the field of engineering education and aims to address the semantic gap between project practice and theoretical instruction. Relevant research has primarily focused on two aspects: knowledge mapping algorithms and quantitative evaluation of educational resources. However, existing solutions remain insufficient in tracing the theoretical origins of engineering practice tasks. Therefore, based on the OBE philosophy, this study designs a reverse-driven system architecture, aiming to bridge the deficiencies of the aforementioned research through standardized modeling and vector alignment.

2.1. Semantic Alignment of Curriculum Knowledge and Engineering Tasks

Automated alignment of curriculum knowledge points in engineering education serves as the foundation for dynamic revision. Molavi et al. [3] proposed an embedding-based ranking framework that maps educational resources to learning objective spaces using large language models, demonstrating the effectiveness of vector space representation in handling heterogeneous educational data. Regarding the alignment of curriculum with market demands, existing research [4] has explored a framework that correlates curriculum content with professional skills through cosine similarity calculations, which provides an algorithmic paradigm for this study to treat “engineering tasks” as vector queries for matching against a “theoretical knowledge base.” Given the specific semantic complexity inherent in engineering education, Daugherty [5] emphasized the necessity of theoretical reconstruction of engineering practices through concept maps as early as 2011, noting that the lack of explicit theoretical attribution is a primary cause of the disconnection between curriculum content and practice. Although the original research was largely based on manual analysis, the mapping logic proposed provides an essential logical starting point for this study to achieve automated theoretical reconstruction via AI models.

2.2. AI-Based Knowledge Modeling and Evaluation Methods

With the development of deep learning, automated knowledge graph construction and evaluation have become the core of educational data mining. Addressing knowledge representation in the engineering domain, Lai et al. [6] proposed a knowledge graph-based method for engineering education construction, which provides an effective path for building high-precision theoretical knowledge bases through the systematic organization of domain entities and relationships. Furthermore, under the Outcome-Based Education (OBE) model, some studies [7] have validated the effectiveness of Natural Language Processing (NLP) technology in automating the mapping between Course Outcomes (CO) and Program Outcomes (PO). This research demonstrates the potential of reducing manual assessment bias through semantic analysis. Compared to traditional mapping methods that rely on human experience, the BAAI/bge-small-zh-v1.5 model selected for this study exhibits greater robustness in handling short-text semantic alignment through instruction fine-tuning, enabling more precise capture of the theoretical support implicit in engineering tasks, thereby compensating for the limitations of existing research in heterogeneous task representation.

3. System Architecture Design Based on the OBE Philosophy

This study adopts a reverse-design approach to establish a complete logical framework covering theoretical instruction, project practice, alignment mapping, and closed-loop decision-making, thereby integrating curriculum development with engineering practice.

3.1. Foundational Construction of Theoretical Knowledge

The knowledge points within the cultivation program are standardized. This process goes beyond simple categorization into chapters or sections; rather, it involves defining the attributes of each knowledge point—such as “mathematical foundations,” “engineering algorithms,” “system architecture,” or “business logic”—to provide metadata support for semantic alignment.

3.2. Top-level Project Matrix Design

When designing projects, it is essential to construct a plan featuring progressively advancing capabilities. The first year of undergraduate study serves as the professional foundation stage, during which project focus should be placed on engineering literacy, toolchain proficiency, and fundamental Linux operations. The second year represents the integration stage of theory and practice, focusing on incorporating core foundational course knowledge into project practice and emphasizing the engineering validation of algorithms. The third year is designated as the system integration stage, where students concentrate on distributed architecture, big data, and real-time processing, with a focus on system design and engineering implementation. The fourth year is known as the frontier innovation stage, where project design should prioritize large language models, advancements in deep learning, and system performance optimization.

4. Methodology for Knowledge Point Mapping

The transformation of engineering descriptions into theoretical expressions is the critical step for achieving the alignment between curriculum knowledge and project

knowledge points. By constructing standardized conversion criteria and semantic vectorization algorithms, this study achieves deep logical-level alignment between the two.

4.1. Theoretical Conversion Criteria for Project Tasks

To eliminate semantic bias and ensure the academic rigor of project task descriptions, a set of structured modeling criteria is introduced to reconstruct engineering tasks into standardized expressions, thereby enabling direct mapping to the curriculum knowledge base. The standardized mapping expression is simplified as $T=(A,E,C)$, where A represents the action verb, E represents the engineering object, and C represents the theoretical domain. When applying these criteria, the reconstruction of each task must adhere to three core requirements. The action verb A relies on the Bloom's Taxonomy categories to define the core cognitive operations performed by students during the project. The engineering object E defines the system entity or data carrier upon which the task acts. The theoretical domain C explicitly identifies the underlying course theory supporting the operation, enforcing the attribution of engineering tasks to theoretical disciplines. Through this standardized reconstruction, the dispersion of engineering descriptions is effectively reduced, thereby ensuring the rigor of semantic computation and the accuracy of curriculum traceability.

4.2. Algorithmic Model Decision for Semantic Mapping

Following the establishment of standardized conversion criteria, this study realizes the automated matching between project knowledge points and curriculum knowledge points by constructing a semantic vector retrieval system. Regarding model selection and preprocessing, considering the differences in terminology usage between engineering language and theoretical descriptions, the BAAI/bge-small-zh-v1.5 Chinese semantic model is selected. This model possesses excellent text representation capabilities; through instruction fine-tuning, it significantly enhances the relevance representation of heterogeneous texts within the semantic vector space, thereby effectively improving the semantic alignment between engineering descriptions and theoretical definitions. Regarding similarity calculation and mapping strategies, the system first transforms all theoretical knowledge points in the curriculum program into high-dimensional vectors via the model and stores them in a vector index database. The project task descriptions, after undergoing the aforementioned modeling paradigm transformation, serve as query vectors. By calculating the cosine similarity between project task vectors and curriculum knowledge point vectors, a matching matrix is established. Through the setting of thresholds, the coverage of curriculum knowledge points by project practice is quantitatively evaluated, providing objective data evidence for the subsequent dynamic revision of cultivation programs, and achieving an optimization of the cultivation system from qualitative experience-based configuration to quantitative data-driven decision-making. (Figure 1)

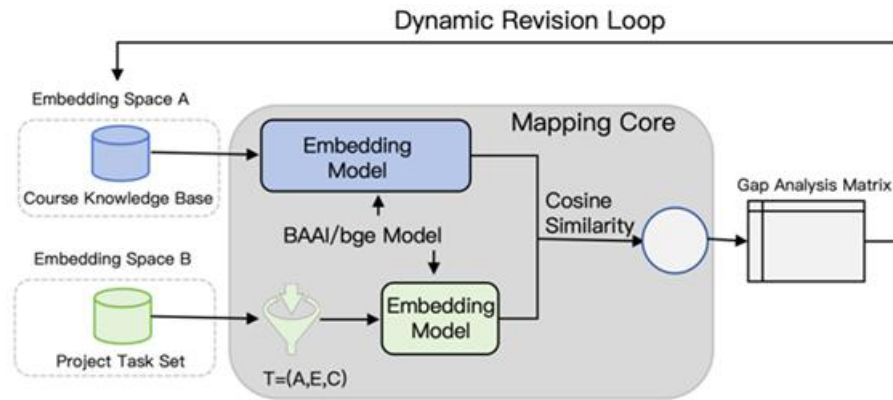


Figure 1. Overview of the Proposed Theoretical Mapping Framework.

5. System Implementation and Evaluation Feedback Loop

5.1. Semantic Mapping and Quantitative Calculation Path

Achieving alignment between project knowledge points and curriculum theory requires a standardized engineering data processing workflow. The system adopts a hybrid mode incorporating vector representation, semantic search, and human expert intervention to ensure the rigor of the computation.

Table 1. Detailed Breakdown of Implementation Steps.

Stage	Core Task	Technical Basis and Processing Logic
Data Standardization	Cleaning of Knowledge Base and Project Base	Standardize semantic format; rewrite task descriptions by applying the “Action Verb + Object + Theoretical Support” specification.
Vectorization Transformation	Semantic Space Mapping	Employ the BGE-small-zh-v1.5 model to vectorize standardized text and establish high-dimensional feature vectors.
Similarity Calculation	Vector Cosine Similarity Matching	Utilize the FAISS vector engine to calculate the distance between project tasks P and curriculum knowledge points C, establishing a matching matrix.
Threshold-based Decision	Three-level Mapping Differentiation	Perform classification (strong mapping, weak association, or mapping disconnection) based on the similarity threshold S.
GAP Diagnostic Report	Basis for Program Revision	Generate targeted curriculum addition/deletion logic reports based on the system’s computational results.

5.2. Decision-making Feedback Loop System Based on Similarity Thresholds

The system does not directly determine the inclusion or removal of courses but instead generates assessment reports to provide decision-making evidence for the faculty expert group. This study sets the similarity score S as the basis for dynamic adjustment. The strong mapping interval ($S > 0.85$) is regarded as a high degree of coupling between the theoretical system and the project. Within this interval, the focus should be on strengthening the design of experiments for “theoretical instruction to engineering practice” to ensure the knowledge conversion rate. The weak association interval ($0.6 < S < 0.85$) suggests that the theory is related to the project, but the current depth of engineering practice coverage is insufficient. The corresponding strategy at this stage is to supplement curriculum experiments with specialized lectures or demonstrations of engineering cases. The mapping

disconnection interval ($S < 0.6$) is considered a critical warning zone. If a specific engineering task is disconnected across all projects from the sophomore to senior years, it indicates that the existing cultivation program lacks necessary engineering support, or that the project topics have deviated from the syllabus.

6. Dynamic Revision Mechanism for Cultivation Programs Based on Semantic Gap Reports

The revision of talent cultivation programs serves as the foundation for academic planning in universities. During the implementation of Project-Based Learning, a significant semantic gap exists between the engineering knowledge points derived from projects and the theoretical knowledge points derived from courses. The semantic gap report, referred to as the “GAP report,” facilitates a shift in program revision from being driven by subjective experience to being driven by data evidence. Decisions regarding the revision of cultivation programs are executed based on the GAP report, which is output by the system and contains detailed data.

6.1. Knowledge Filling Strategies

If the system detects that a certain type of engineering skill appears frequently across multiple key tasks but cannot be identified by the existing curriculum knowledge base, it will automatically trigger a knowledge filling process; this involves establishing additional courses associated with this knowledge point. Furthermore, in such situations, curriculum expansion can also be implemented. The strategy for curriculum expansion is to introduce relevant knowledge points into an existing related course through modular insertion, rather than creating a new course. If the knowledge gap is too extensive, prerequisite engineering courses can be established to meet the project’s requirements. For example, offering seminars on engineering frontiers or specialized engineering experiments falls into the category of prerequisite courses.

6.2. Knowledge Redundancy Reduction Strategies

After calculating the similarity between project and curriculum knowledge points, for courses that consistently fall into the similarity score range of $S < 0.6$ and are not part of the professional core theoretical foundation, the system will initiate reduction or provide a warning. If two courses show low mapping degrees for their theoretical knowledge points, their theoretical overlap should be analyzed to consider merging them into a more comprehensive applied course. The learning time allocated to certain outdated theoretical knowledge points can be reallocated to project practice; this content can be designated as self-study material regarding the principles of program implementation, while the credit hours are redistributed to practical segments with higher degrees of engineering focus and better mapping alignment.

7. Conclusions

The knowledge mapping framework based on semantic alignment proposed in this study is not merely an automated technical attempt, but a systematic and rigorous practice of the Outcome-Based Education (OBE) philosophy. By aligning abstract theory with concrete engineering projects within the same semantic space, educational administrators can clearly identify missing or redundant courses and content within talent cultivation programs. In the future, this system will gradually introduce

dynamic evolution logic for knowledge graphs, enabling cultivation programs to undergo version iterations in line with the rapid changes in the industry, thereby truly achieving a high degree of synchronization between talent cultivation and industrial demands.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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