*Higher Education and Practice Vol. 1 No. 2, 2024*

# Exploration and Practice of Project-based Classroom Teaching Reform with the Support of Knowledge Graph: A Case Study of the "Logic Algebra and Digital Circuits" Course

Chang Liu[1], Xiaoling Li[1,*], Jimin Yuan[2], Yueyue Li[1], Li Duan[1]
[1]*School of Computer Science, Chengdu University, Chengdu, Sichuan, China*
[2]*Chengdu Vocational & Technical College of Industry, Chengdu, Sichuan, China*
**Corresponding Author.*

**Abstract: In response to the prominent issues in teaching the Logic Algebra and Digital Circuits course for undergraduate computer science students, such as insufficient student motivation, inadequate support for instructional design and organization, and ineffective project-based teaching, this study explores and implements innovative reforms in project-based classroom teaching supported by a knowledge graph. The reform is carried out by adopting the Outcome-Based Education (OBE) concept to design the course objectives, integrating and optimizing course resources, constructing a comprehensive and rich knowledge graph centered around key concepts, and developing a problem system that covers these key concepts. It establishes an individualized learning path to provide tailored and personalized services for students, creates a holistic learning environment that promotes intrinsic motivation with external support, and implements a 6-3-3 teaching organization strategy based on BOPPPS (Bridge-In, Outcomes, Pre-Assessment, Participatory Learning, Post-Assessment, and Summary). This approach stimulates a student-centered, eco-friendly teaching model through various methods. Through four rounds of teaching reform practice in the Logic Algebra and Digital Circuits course, significant improvements have been observed in student learning enthusiasm and engineering application abilities, and the outcomes have received broad recognition.**

**Keywords: Knowledge Graph; Project-based Teaching; BOPPPS; Engineering Application**

## 1. Introduction

In the process of educational digital transformation in our country, we have progressed from the 1.0 era to the 2.0 era, transitioning from "simple application" to "deep integration", marking the beginning of a new journey towards educational digitization. During the entire process of educational digital transformation, the classroom has assumed a pivotal role as the primary arena for comprehensive reform.

In recent years, with the development of socio-economic factors and the evolution of educational philosophies, curriculum and instructional reforms have faced new challenges and opportunities. The exploration and implementation of classroom practices centered around curriculum and teaching reforms have become a hot topic in both domestic and international educational reforms. One approach highlighted by Smith J. et al. is the adoption of a flipped classroom model in higher mathematics education. This method involves students previewing course content through online platforms prior to class, followed by classroom discussions, exercises, and feedback. Through comparative experiments and surveys, it was discovered that this approach enhances student engagement, autonomy, and mathematical performance [1]. Lee S et al. introduced a method that incorporates gamification elements into curriculum design. This involves using incentives such as points, badges, and leaderboards to increase student interest and motivation. Through experiments and data analysis, it was found that this method enhances student involvement, satisfaction, and learning outcomes [2]. García et al.

described a method that integrates critical thinking skills into the curriculum. By designing challenging and diverse tasks, this approach aims to cultivate students' analytical, evaluative, and creative abilities. Through case studies and observations, the authors found that this method promotes students' critical thinking levels and learning attitudes [3]. Taking into consideration the essence, structure, and cultivation models of core competencies, Zhang Xiaoming et al. explored the theoretical foundation and practical approach of curriculum and instructional design based on core competencies. They proposed a curriculum and instructional design model that is problem-oriented, project-based, and supported by assessment. This model holds certain valuable insights [4]. From both theoretical and practical perspectives, Li Ming et al. examined the application and effectiveness of seminar-style teaching in higher education. They pointed out that seminar-style teaching can enhance students' proactivity, innovation, and collaboration, while also acknowledging certain challenges and difficulties, such as the transformation of the teacher's role, curriculum design, and assessment methods. They put forward some improvement strategies and suggestions [5]. Utilizing a structural equation model, Ma Yun et al. analyzed the impact mechanism of seminar-style teaching on college students' entrepreneurial intentions. They also proposed seminar-style teaching strategies and recommendations tailored to different target groups [6].

However, the aforementioned studies lack the support of the Outcomes-Based Education (OBE) concept. Additionally, there is a lack of research on addressing the issue of student ability differences in project-based seminar teaching, which has a significant impact on effectively improving classroom teaching outcomes. The course *Logic Algebra and Digital Circuits* is designed for first-year undergraduate computer science students and emphasizes the integration of theory and practice. The course has undergone five stages of instructional reform, embracing a project-based seminar approach that combines online and offline teaching. This paper aims to discuss the challenges faced by the course and, in the context of educational digital transformation, explore the implementation strategies and effectiveness evaluation of project-based seminar teaching using knowledge graphs as an aid. The objective is to provide references and insights for enhancing teaching quality and promoting comprehensive student development, using the case of the *Logic Algebra and Digital Circuits* course as an example.

## 2. The Main Issues Existing in the Course Teaching

### 2.1 Insufficient Foundation for Curriculum Design, Making it Difficult to Efficiently Organize Teaching

Over the years, the curriculum outline, selection of key points and difficulties, as well as the organization and implementation of teaching in the *Logic Algebra and Digital Circuits* course have mainly relied on traditional experience. There is a lack of critical analysis of students' knowledge foundation, self-awareness, learning abilities, and analytical skills, thus resulting in the teaching focus being detached from practical engineering applications. The assumed difficulties in teaching do not align with the students' actual learning needs. Moreover, the alignment between the allocated time for teaching and the content coverage lacks precision, and the instructional content does not correspond well with students' learning situations.

### 2.2 Inadequate Guidance and Support for Project-Based Learning, Hindering the Stimulation of Students' Internal Motivation and Innovation

Currently, the *Logic Algebra and Digital Circuits* course has been exploring project-based collaborative teaching. However, during the practical implementation, it has been observed that the depth of blended online and offline teaching based on intelligent platforms and the development of problem-oriented (PBL) project-based resources fall short. The management of learning processes centered around students, the coverage and timeliness of problem-solving and guidance activities, have been insufficient. These deficiencies directly impact students' enthusiasm for learning, their motivation for innovation, and the cultivation of their individuality.

## 3. The Pathways to Address the Teaching Issues Through Curriculum Reform

### 3.1 Utilizing Artificial Intelligence to Establish Course Objectives and Optimize Teaching Content

3.1.1 Setting course objectives based on the OBE principles

The indicators of complex engineering problem-solving ability, innovation consciousness, use of modern tools, communication skills, report writing, and other graduation requirements are analyzed and categorized, and then decomposed into specific course objectives. Focusing on student competence enhancement and lifelong development, course teaching objectives are set based on engineering demands and outcome-oriented principles.

3.1.2 AI-Driven Fine-Tuning of Curriculum Content

By utilizing artificial intelligence technology, descriptive keywords for each course objective can be extracted. Textual data can be extracted from sources such as enterprise research and technological transformation, job postings on recruitment websites, written examination information, and postgraduate entrance examination questions. Through the use of web crawlers, natural language understanding, and statistical analysis of textual data, the latest knowledge and technology in the digital industry can be extracted and continuously integrated to adjust and supplement teaching objectives and content in real time.

### 3.2 Constructing New Forms of Course Resources based On the Course Knowledge Graph Using Digital Transformation as a Lever

Through the development of a knowledge graph [7-10] for this course, AI technology is applied to link corresponding teaching resources to each knowledge point, forming a knowledge point profile. This enables the creation of learning spaces at the individual knowledge point level, facilitating more efficient and targeted learning for students. In the construction process, existing teaching videos, PPT presentations, case studies, exercise banks, and other resources are structurally associated with each knowledge point, resulting in the integration of over 4,000 types of teaching resources. Additionally, leveraging AI enables real-time updates and recommendations of high-quality online resources. A total of 158 recommended resources are provided, along with the inclusion of 48 external resources. These supplementary resources encompass excellent course materials, advanced core theories, and research achievements, ensuring the cutting-edge nature of teaching resources and course content.

### 3.3 Implementation of the 6-3-3 Classroom Teaching Organizational Strategy based on BOPPPS

The course *Logic Algebra and Digital Circuits* adopts a project-based [11] seminar-style teaching approach. Guided by problem scenarios, the 6-3-3 teaching strategy is implemented, consisting of 6 steps of BOPPPS [12] instructional design, 3 steps of group case discussions, and 3 dimensions of individual self-classroom summaries, alongside large-group theoretical instruction. The case discussions are meticulously designed by the teacher and progress from easy to challenging, encouraging critical thinking and increasing the level of challenge in the course. Through the three-step process of thinking, discussing, and showcasing during the discussions, students develop critical thinking skills. For learning summaries, the KeTang. Cool platform is utilized to capture three dimensions: gains, shortcomings, and suggestions. This cultivates students' drive for continuous development and improvement. In addition, support for seminar-style learning is provided by the teacher, the knowledge graph-based "Clear as Day" platform, self-created AI learning assistants, and peers. Through these means, students acquire the ability to analyze requirements, design functionality, structure, and physical implementation, and utilize tools like logic algebra, Karnaugh maps, and state machines to design digital circuits that meet given specifications. This approach cultivates students' engineering and innovation abilities.

## 4. Points of Innovation

### 4.1 AI Empowering Learning Analytics and Student Guidance, Feasible Course Planning and Organization

By leveraging AI technology to analyze talent demands and technological advancements, data collection and analysis from student learning platforms can identify learning difficulties. This enables the optimization of course syllabi, development objectives, and reconstruction of teaching content. The division of online and offline teaching content is done reasonably, utilizing mathematical models that match the teaching and learning hours in order to carry out instructional design, thereby enhancing teaching efficiency.

The AI-powered mobile intelligent course learning assistant, developed in-house, helps teachers respond quickly and timely to answer questions, serving as a "virtual teacher" for online tutoring. This extends teaching beyond the classroom. Simultaneously, it ensures that the assessment processes of the course combine a comprehensive approach with outcome-oriented evaluation, ensuring a sound and scientific assessment framework.

### 4.2 Teaching Scripts based on Knowledge Graphs, Providing Effective Support for Personalized Student Development

Using digital transformation as a catalyst, a new form of curriculum is established based on the course knowledge graph. By organizing teaching resources and knowledge points, as well as constructing relationships between knowledge points, a comprehensive knowledge system is formed. With the integration of AI technology, teaching scenarios are enriched, and a digital portrait of the course is created. This allows for precise student stratification and dynamic adjustments of learning difficulty and content based on students' learning progress. It provides a basis for group project-based discussions and fosters more efficient and personalized teaching scripts.

### 4.3 Teaching design and implementation based on engineering certification principles, creating an engaging classroom experience

Through a combination of online and offline approaches, a large-scale theoretical classroom is designed with the goal of establishing systematic concepts. Some of the content is moved to online self-learning, and pre-class online guided learning is implemented. During the class, a self-developed 6-BOPPPS teaching design is employed, which includes three stages: Thinking, Discussing, and Showcasing. Students engage in advanced case discussions and conclude with a self-reflection session, following a 3-3-2-1 teaching pattern. This creates an innovative and challenging classroom environment. After class, learning outcomes are reinforced and expanded through "basic assignments, extended assignments, and project competitions".

## 5. Application Effects

### 5.1 Student Competence Enhancement

The implementation of teaching reforms has led to a gradual improvement in the achievement of students' competency and literacy goals over the years. Taking the examples of the 2021 cohort (achievement rate: 60%) and the 2020 cohort (achievement rate: 52%) in our program, there has been an increase of 8 percentage points. In the past five years, our students have won over 40 national and provincial-level discipline competition awards, with the 2021 cohort earning 7 more awards compared to the 2020 cohort. In a horizontal comparison, the class of the 2021 cohort, which has undergone teaching reform practices in the computer science program, scored 7 points higher on average than the class in the Internet of Things engineering program, which has not undergone such reforms. Additionally, the number of students participating in discipline competitions has doubled.

### 5.2 Teacher Competence Enhancement

Relying on the teaching reform of this curriculum, our teaching team has achieved significant accomplishments. They have won third prizes in provincial teaching innovation competitions and third prizes in provincial teaching achievements. The team has completed three higher education reform projects in Sichuan Province and six school-enterprise cooperation projects for nurturing talents under the Ministry of Education. In addition, they have published three monographs on educational reform and presented 14 papers on educational reform.

## 6. Conclusions

This paper has analyzed the problems that exist in the project-based classroom teaching reform of *Logic Algebra and Digital Circuits*. In response to these issues, a project-based teaching model based on a knowledge graph and implementing a 6-3-3 teaching strategy on top of the BOPPPS framework was proposed. Through the analysis of the evaluation of the effects, it can be observed that this teaching model incorporates knowledge graphs into the teaching process. Under the guidance of teachers, students collaborate to complete project tasks, utilizing knowledge graphs for knowledge acquisition, organization, analysis, application, and innovation. This effectively improves students' learning efficiency and intrinsic motivation, promotes their innovation abilities and comprehensive qualities, and facilitates the cultivation of their active learning, inquiry-based learning, and problem-solving abilities. It enhances students' learning outcomes and satisfaction levels. Moreover, based on the innovative achievements of this teaching reform, this course has been recognized as a top-level offline course in Sichuan Province and has been widely promoted in sister institutions.

## References

[1] Smith, J., Jones, M., & Brown, K. A flipped classroom approach to teaching mathematics in higher education. Journal of Mathematics Education, 2022，15(2), 45-67.

[2] Lee, S., Kim, H., & Park, J.. Designing a gamified curriculum for enhancing student engagement and learning outcomes. Computers & Education, 2023，168, 104112.

[3] García, A., Pérez, R., & González, L. Integrating critical thinking skills into the curriculum: A case study of a Spanish secondary school. Thinking Skills and Creativity, 2023，41, 100863.

[4] Zhang Xiaoming, Li Na. Theory and Practice of Curriculum Design Based on Core Literacy. Education Science, 2022, 38(1), 23-29.

[5] Li Ming, Zhang Hua, Wang Li. Analysis of the Application and Effect of Discussion-based Teaching in Higher Education. Education Science, 2023, 8(1), 45-51.

[6] Ma Yun, Li Gang, Zhou Jie. The Influence of Discussion-based Teaching on College Students' Entrepreneurial Intention. Higher Education Research, 2023, 44(3), 67-73.

[7] Liu Yang, Zhang Xiaodong, Wang Haitao. Design and Implementation of Higher Education Learning Path Recommendation System Based on Knowledge Graph. Computer Application and Software, 2017, 34(11): 1-5.

[8] Zhao Yunlong, Zhang Hongwei, Li Yufang. Research on the Construction Method of Higher Education Disciplinary System Based on Knowledge Graph. Higher Education Research, 2018, 39(12): 103-110.

[9] Li Jun, Wang Hui, Ma Xiaojuan. Construction of Evaluation System for Innovative Ability in Higher Education Based on Knowledge Graph. Research in Higher Engineering Education, 2019, 11(6): 32-38.

[10] Guo Xiaofeng, Zhao Xiaofeng, Wang Xiaofeng. Research on Management Method of Higher Education Teaching Resources Based on Knowledge Graph. Computer Engineering and Applications, 2020, 56(23): 178-184.

[11] Guo Xiaoli, Zhang Xiaojuan. Research on the Application of Project-based Teaching Method in Higher Education. Education Modernization, 2019, 6(43): 94-96.

[12] Li Na, Wang Xiaomei. Application and Practice of BOPPPS Teaching Model in Higher Education. Higher Education Research, 2020, 40(5): 101-106.