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GenAI-Empowered Teaching Model Integrating SPOC and BOPPPS

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Abstract: *With the rapid advancement of educational digitisation and generative artificial intelligence (GenAI), current teaching faces challenges such as low utilisation of MOOC resources and insufficient interaction between teachers and students. To address these issues, this study constructs a GenAI-empowered teaching model integrating SPOC and BOPPPS. GenAI is employed to generate and optimise content, recommend personalised learning pathways, and support intelligent conversational interaction. SPOC provides a structured online learning environment for pre-class and post-class activities, facilitating the construction of knowledge graphs. BOPPPS offers a clear framework for in-class teaching. This study implements the constructed GenAI-empowered SPOC and BOPPPS hybrid teaching model in the Operations Research course over a complete teaching semester. Analysis of final exam scores, SPOC learning data, and classroom teaching observation data from three classes showed that the experimental group achieved a higher average score than the control group, along with significantly enhanced learning motivation and classroom engagement.*

Keywords: *Small Private Online Courses (SPOC), BOPPPS, Generative Artificial Intelligence (GenAI), Teaching Reform*

1. Introduction

With the development of educational digitisation, the pursuit of teaching quality is increasingly heightened. The emergence of new information technologies drives the renewal of teaching methods while inevitably introducing new challenges. Currently, classroom teaching for many courses still faces several difficulties. Online resource utilisation is low; despite the development of rich Massive Open Online Courses (MOOC) resources, student participation and completion rates often remain unsatisfactory, and integration with offline teaching tends to be superficial. The interaction is limited; traditional lecture-based classrooms are often teacher-centered, with limited student participation and insufficient discussion.

The digitisation and intelligence in education are reshaping higher education. Generative artificial intelligence (GenAI), represented by large language models, has rapidly permeated teaching and learning in higher education, altering not only how students access information but also how teachers design tasks, provide feedback, and conduct assessments. An increasing number of studies explore the application of GenAI in teaching, such as content generation, formative feedback, scaffolding, and co-creation of learning materials [1][2][3]. Despite concerns regarding academic integrity and over-automation, many studies argue that, with proper guidance, GenAI can serve as a cognitive partner to support critical thinking, problem-solving, and personalised learning [4][5].

Small Private Online Courses (SPOC), evolving from MOOC [6][7], provide a targeted, small-scale online learning environment particularly suited for blended and flipped classroom models [8]. Relevant empirical studies indicate that compared to traditional lecture-based teaching, the SPOC blended with the flipped classroom model can significantly improve the academic ability of students [9][10][11][12]. For instance, applying SPOC and the flipped classroom to the teaching of Advanced Mathematics led to significant improvements in conceptual understanding and problem-solving abilities of students [11]. Similarly, applying this model to the Data Structures and Algorithms course effectively enhanced the

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programming skills and teamwork capabilities of students [12]. However, the model of SPOC blended with the flipped classroom also has shortcomings in practice. For example, it places higher demands on students' self-directed learning abilities; without effective guidance and supervision, it may lead to a polarisation of learning outcomes. Furthermore, the seamless integration and deep alignment of online and offline teaching content remain challenging.

The BOPPPS model, originating in Canada, divides a lesson structure into six elements: Bridge-in, Objective, Pre-assessment, Participatory Learning, Post-assessment, and Summary [13]. It has been widely adopted in higher education to enhance classroom structure, student engagement, and learning outcomes. Research shows that models based on BOPPPS or its integration with other teaching methods are effective in promoting interaction, improving grades, and supporting outcome-based education [14][15][16]. For example, [15] applied BOPPPS to the teaching of Physiology Education, effectively improving teaching effectiveness and student satisfaction. [16] used BOPPPS in Organic Chemistry Laboratory teaching, significantly increasing the participation and knowledge retention. However, the traditional BOPPPS model shows limitations in addressing personalised teaching needs in large classes, dynamically generating teaching content, and handling complex, open interdisciplinary problems. It requires integration with new technological tools to meet the development of digitisation and intelligence in education.

The integration of information technology and artificial intelligence (AI) is driving a profound transformation in pedagogical methods. Blended teaching models combining online and offline elements, facilitated by advanced technological means, have gradually become a significant direction for global teaching reform. Existing work often focuses on pairwise combinations: SPOC and BOPPPS [17] can effectively integrate online resources with offline interaction but have limited intelligence, making personalisation difficult; GAI and SPOC [18] can provide intelligent content and tutoring but lack systematic support from a structured offline classroom teaching framework; GAI and BOPPPS [19] can enhance the intelligence and interactivity of classroom segments, but the support system for continuous learning before and after class needs improvement. There is a scarcity of research that systematically integrates GenAI, SPOC, and BOPPPS into a cohesive pedagogical model and demonstrates its application in a specific course [20]. A logical progression is to systematically integrate the three: SPOC provides a structured, trackable online learning space, BOPPPS offers a goal-focused, interactive offline teaching framework, and GenAI acts as an intelligent engine, permeating pre-class, in-class, and post-class stages to provide content generation, personalised pathways, real-time interaction, and in-depth analysis. This integration has the potential to achieve personalised resources, precise teaching and process-based evaluation. This leads to the construction of a closed-loop, intelligent teaching ecosystem that seamlessly connects online and offline while integrating human-machine collaboration.

This study aims to construct a GenAI-empowered SPOC blended with the BOPPPS teaching model, investigating its roles and mechanisms across the pre-class, in-class, and post-class stages. Using the Operations Research (OR) course as the teaching implementation context, it elaborates on the implementation process and effectiveness of this teaching model through specific teaching practice.

2. Construction of the GenAI-Empowered SPOC and BOPPPS Hybrid Teaching Model

2.1. Model Framework

The GenAI-empowered SPOC and BOPPPS hybrid teaching model (see Figure 1) integrates three core components.

• SPOC serves as the online learning vehicle for pre-class and post-class study;

• BOPPPS functions as the frame for in-class instructional design;

• GenAI acts as the intelligent engine for content recreation, interaction support, and personalised learning pathways.

This model fully integrates GenAI, SPOC, and BOPPPS. The specific teaching implementation unfolds across the following three phases.

(1) Pre-class: Activating prior knowledge, guiding preview, and diagnosing learning readiness.

(2) In-class: Deepening understanding through interactive, case-based activities.

(3) Post-class: Consolidating and extending learning with personalised support.

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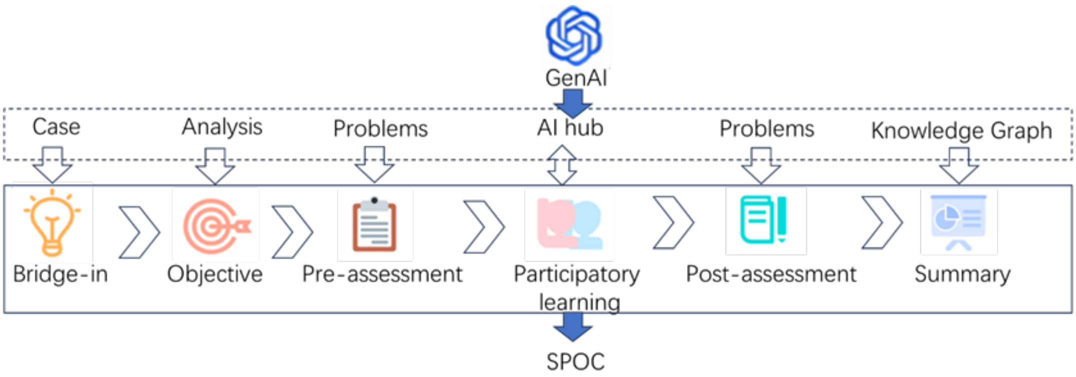

Figure 1. The Teaching Model

2.2. Pre-Class Phase

In the pre-class phase, an online self-directed learning environment is established based on the SPOC platform, integrated with GenAI technology. This phase systematically implements the "Bridge-in" (B), "Objective" (O), and "Pre-assessment" (P) elements of the BOPPPS model. Emphasising a student-centered approach, students review learning objectives on the SPOC platform, complete assigned online course materials and case previews, and undertake a GenAI-assisted pre-assessment to prepare content-wise and cognitively for the classroom session.

(B) Bridge-in

Teachers utilise GenAI to generate personalised introductory cases that are closely linked to teaching objectives and characterised by disciplinary context. These cases are sent to specific classes via the SPOC platform. The content, tailored to students' academic backgrounds and real-world application scenarios, aims to stimulate learning interest, establish connections between new knowledge and existing experience, and naturally guide students into the learning topic.

(O) Objective

Leveraging GenAI's analysis of curriculum standards and learning data, clear, measurable, and tiered learning objectives are generated and explicitly presented to students on the SPOC platform. Guided by these objectives, students are required to watch relevant videos, study preparatory cases and foundational materials, thereby forming an initial cognitive framework for the upcoming in-class content.

(P1) Pre-assessment

Teachers employ GenAI to generate pre-assessment questions covering different cognitive levels. After manual review and refinement, these questions are sent to students via the SPOC platform. The system provides immediate feedback on responses, while GenAI simultaneously generates personalised learning analysis reports. This helps teachers accurately identify students' mastery of prerequisite knowledge and common weaknesses, providing a basis for in-class instructional design.

2.3. In-Class Phase

The in-class phase focuses on the "Participatory Learning" (P), "Post-assessment" (P), and "Summary" (S) stages of the BOPPPS model, incorporating GenAI's intelligent support. Simultaneously, Rain Classroom is utilised to facilitate real-time interaction, enhancing classroom engagement and teaching effectiveness.

(P2) Participatory Learning

Participatory learning in the classroom, organised under the teacher's guidance, revolves around three core segments. First, students engage in group analysis and discussion centered on cases generated by GenAI. During this process, with teacher facilitation, students can interact with GenAI tools in real-time to explore multiple solution paths. By critically comparing their approaches with AI-generated solutions, they deepen their understanding of disciplinary methods and their application boundaries. Subsequently, the teacher conducts systematic case analysis on typical problems, helping students build a cognitive foundation. Finally, theoretical explanations and generalisations are provided for the concepts involved in the case analysis.

(P3) Post-assessment

Teachers assign quizzes focusing on the key points of the lesson via platforms like Rain Classroom. The content encompasses core concept discrimination. The system supports automatic grading for objective questions, while GenAI can assist teachers in generating personalised, formative feedback based on common student errors, facilitating immediate learning diagnosis and instructional adjustment.

(S) Summary

Teachers guide students in systematically reviewing and synthesising the lesson content. Leveraging real-time data analysis results from the teaching platform, the performance characteristics of students during participatory learning and the post-assessment are clarified. Through the GenAI-empowered SPOC platform, a visual knowledge graph is generated, clearly illustrating the internal connections and evolutionary pathways among "core concepts—typical problems—solution methods." Building upon the graph, the teacher further emphasises knowledge points and common misconceptions, helping students form a structured knowledge system and providing direction for subsequent learning.

2.4. Post-Class Phase

The post-class phase, based on the SPOC platform and supported by GenAI, provides students with personalised, structured support for consolidation and extended learning. This phase focuses on deepening understanding, integrating knowledge, and extending capabilities, promoting the continuous reinforcement of learning outcomes.

2.4.1. Personalised Extended Learning

Based on the learning behaviour data from both the classroom and the SPOC platform, GenAI generates differentiated extended learning materials, including foundational exercises and case studies, which are then pushed to corresponding students via the SPOC platform. Simultaneously, the system allows students to autonomously select extension tasks within parameters set by the teacher, balancing foundation consolidation and challenge advancement based on their individual interests and needs.

2.4.2. Structured Integration of Knowledge System

With the assistance of GenAI, teachers systematically organise the course knowledge framework, progressively constructing and dynamically updating a visual course knowledge graph. Students can autonomously navigate, query, and explore the relationships between nodes within the graph on the SPOC platform, deepening their understanding of the logical chain connecting "concepts—methods—applications" and promoting knowledge systematisation and transfer.

2.4.3. Sustained Intelligent Interaction Support

On the SPOC platform, GenAI serves as an instant Q&A assistant, providing students with answers to common questions and learning resource recommendations. This establishes a human-machine collaborative interaction mechanism, enhancing feedback efficiency.

3. Implementation of the GenAI-Empowered Hybrid Teaching of integrating SPOC and BOPPPS in the Operations Research Course

3.1. Course and Student Profile Analysis

Operations Research is a compulsory course for students majoring in Logistics Management, Supply Chain Management, Engineering Management, Emergency Management, Data Science, Statistics, and Mathematics at our university. Students have completed prerequisites in Calculus and Linear Algebra, but exhibit differences in mathematical preparedness and application experience. Common challenges include the abstract understanding of optimisation concepts, difficulties in formulating mathematical models, and varying perceptions of Operations Research problems across different majors.

3.2. Teaching Resource Preparation

3.2.1. Teaching Content and Case Development

The course content was systematically divided into eight sections: Linear Programming, Duality Theory, Sensitivity Analysis, Transportation and Assignment Problems, Integer Programming, Goal

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Programming, Dynamic Programming, and Network Optimisation. For each section, the teacher utilised GenAI to generate preliminary cases reflecting disciplinary variations. For instance, in the unit of Transportation and Assignment Problems, the cases are given for different majors as follows.

• For the Supply Chain major: A case on multi-warehouse collaborative distribution optimisation was generated.

• For the Data Science major: A case on dynamic vehicle scheduling based on historical order data was generated.

• For the Engineering Management major: A case on project personnel task assignment and schedule optimisation was generated.

The teacher then checked, revised, and contextualised the GenAI-generated cases to ensure close alignment with professional practice, clear modelling logic, and appropriate difficulty, forming a structured case library.

3.2.2. SPOC Platform Construction

Leveraging the SPOC platform (Rain Classroom), an online learning space was built containing the following resources.

(1) Learning Objectives: Objectives generated based on GenAI, specifying requirements across knowledge, skills, and literacy dimensions.

(2) Course Videos: Recorded segments explaining key and difficult content, supporting fragmented time learning.

(3) Tasks and Quizzes: Preview tasks and pre-/post-assessment questions generated with GenAI, supporting automated grading and feedback.

(4) Knowledge Graph: The platform intelligently presents interconnections among knowledge points based on uploaded resources (videos, slides and notes), supporting student self-navigated learning.

(5) AI Learning Hub: Integrated platform features including AI-powered Q&A, learning path recommendations, and learning behaviour analytics.

3.3. A Case Study of the "Transportation and Assignment Problems" Unit

This course employed Rain Classroom as the SPOC platform. This section details the implementation process for the Transportation Problem.

3.3.1. Pre-Class Phase

Students received learning objectives, tasks, discipline-adapted introductory cases (e.g., Supply Chain majors received the multi-warehouse distribution case), and course videos via Rain Classroom. Using these SPOC resources, they know the learning goals (mastering the basic model of transportation problems and its formulation, setting supply-demand balance conditions and objective functions appropriately for different contexts, and gaining preliminary understanding of solution methods like the Transportation Simplex Method) and an overview of the main content (background and typical scenarios, basic and mathematical model formulation, handling balanced and unbalanced problems, overview of solution methods including the Minimum Cost Method, Vogel's Approximation Method, and their applications in logistics and resource allocation). Students then completed the pre-assessment independently. The system provided immediate feedback and generated individual learning reports. Based on the pre-assessment data, the teacher used GenAI to analyse class readiness and adjusted lecture focus and interactive activities accordingly.

3.3.2. In-Class Phase

To increase participation, the class focused on a case like multi-vehicle type distribution optimisation for Supply Chain majors. Students worked in groups on modelling discussions. During discussions, they could consult GenAI to obtain potential models and analyse their correctness or reasonableness. The teacher primarily acted as a facilitator, using the case analysis to introduce the transportation problem, its model, solution properties, and the Transportation Simplex algorithm. Subsequently, a quiz focusing on the key points was sent via Rain Classroom. The teacher used GenAI to generate diagnostic feedback explanations for common errors, which were then addressed collectively. Finally, the AI assistant on the SPOC platform was used to present a knowledge graph summarising the lesson, highlighting the

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"Problem-Model-Algorithm-Application" logical chain.

3.3.3. Post-Class Phase

Students engaged in open-ended Q&A through the SPOC platform's AI Learning Hub regarding learning difficulties, receiving instant answers and recommendations for extended learning resources and tasks. The teacher assigned homework uniformly via the platform, utilising its AI-assisted grading functions. Based on learning behaviour data and homework performance analysis, the teacher continuously optimised the design of subsequent teaching activities.

4. Teaching Evaluation Methods and Effect Analysis

To emphasise the learning process and assess improvements in knowledge and outcomes, we optimised the course evaluation method to better meet talent cultivation requirements. Moving beyond reliance primarily on homework and final exams for the overall grade, we adopted a diversified evaluation scheme: Online Learning (5%) + Pre-assessment (5%) + Classroom Participation (10%) + Post-assessment (10%) + Lab/Experiment (10%) + Final Exam (60%). This method provides a systematic, multidimensional assessment of student abilities, effectively gauging learning outcomes to ensure teaching quality. Table 1 shows the score rates for the experimental group across all evaluation methods.

Table 1: Score Rates for Various Evaluation Methods

Evaluation Method	Online Learning	Pre-assessment	Class Participation	Post-assessment	Lab	Final Exam
Average Score	98	82	93	89	82	77

As shown in Table 1, the experimental group performed excellently across all formative assessments. The 98% score rate for Online Learning indicates high student engagement and effective utilisation of online resources for self-directed learning. The comparison between Pre-assessment (82%) and Post-assessment (89%) shows a significant improvement, suggesting effective accumulation and consolidation of professional knowledge during the course. The high score rates for Classroom Participation (93%) and Lab/Experiment (82%) reflect active student involvement in interactive, practical teaching segments, demonstrating good hands-on ability and classroom integration. The Final Exam score rate of 77%, while lower than the formative assessment rates, remains within a reasonable range in the diversified evaluation system, indicating appropriate discriminatory power in the summative assessment. Overall, the diversified evaluation method focuses not only on learning outcomes but also values the learning process, encouraging sustained student participation across all stages and facilitating a shift from "final-exam-dominated grading" to "whole-process competency evaluation."

To verify the effectiveness of the GenAI-empowered SPOC+BOPPPS model, this study compared the final exam scores of the experimental group with the control group. The results are shown in Table 2.

Table 2: The Comparison of Final Exam Scores

Group	Student Number	Mean Score	Standard Deviation
Experimental Group	29	77.2	17.6
Control Group	78	67.1	23.0

According to the data in Table 2, the average score of the experimental group is significantly higher than that of the control group. This suggests that the GenAI-empowered "SPOC+BOPPPS" teaching model, through elements like online self-study, classroom interactive participation, and immediate assessment and feedback, enhances student engagement and knowledge internalisation, effectively improving final exam performance.

5. Conclusion

This study designed and implemented a GenAI-empowered SPOC + BOPPPS hybrid teaching model in an Operations Research course, which effectively improved students' academic performance. The integration of SPOC and the BOPPPS framework significantly enhanced pre-class preparation, in-class engagement, and post-class knowledge consolidation. With the support of GenAI, the model provides substantive empowerment at each stage of teaching by enabling content generation, personalised learning pathways, interactive discussions, and timely feedback. In doing so, it addresses instructional challenges that cannot be fully resolved by SPOC or BOPPPS when used independently.

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The proposed model achieves a deep integration of technology, methodology, and pedagogy. Its pedagogical philosophy is grounded in student-centered, data-driven, and interaction-oriented principles. The SPOC platform (Rain Classroom), together with GenAI tools, constitutes the technological foundation, enabling the optimisation of instructional content and the construction of an effective environment for teaching–learning interaction. The BOPPPS instructional design framework systematically orchestrates the entire teaching process. In this model, SPOC functions not merely as a repository for instructional videos but as an integral component tightly connected to in-class activities and post-class learning follow-up. Likewise, GenAI is not employed for isolated demonstrations; rather, it is embedded throughout task design, feedback mechanisms, and knowledge structuring.

Importantly, GenAI, SPOC, and BOPPPS are not simply combined in an additive manner, but are deeply fused to form a coherent instructional system. It should also be acknowledged that GenAI is not entirely reliable. Teachers must carefully review AI-generated content to prevent conceptual inaccuracies or potential biases. Moreover, the effective use of GenAI requires teachers to continuously develop new competencies. We believe that, through ongoing refinement and responsible application of GenAI, the “SPOC + BOPPPS” hybrid teaching model can contribute to the creation of a more intelligent, inclusive, and effective learning environment in higher education.

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