Blended Online and Offline Teaching in Data Structures: An OBE-Based Approach

Shufeng Zhou*, Yueying Zhou, Junsheng Zhao, Hongyan Han, Hongxia Zheng
School of Mathematical Sciences, Liaocheng University, Liaocheng, China
**Corresponding Author.*

Abstract: Focusing on the teaching reform of data structure courses, this paper constructs and practices an online and offline hybrid teaching mode based on the concept of Outcomes Based Education (OBE) in view of the problems of disconnection between theory and practice, single teaching method and imperfect evaluation system existing in the traditional teaching mode. This model takes student ability as the core, and realizes the transformation from "teacher-centered" to "student-centered" by clarifying curriculum objectives, reconstructing teaching content, innovating teaching methods, and reforming the evaluation system. Through a semester of teaching practice, the study uses the method of comparing experimental classes with control classes, and systematically evaluates basic knowledge mastery, practical ability performance, learning process performance and other dimensions. The results show that the experimental class is significantly better than the control class in terms of final exam scores, algorithm design ability, project completion quality and independent learning ability, especially in the understanding and application of complex data structures such as trees, binary trees, and graphs. This study verifies the effectiveness and feasibility of OBE concept and hybrid teaching mode in data structure courses and its methodology of "goal guidance-reverse design-continuous improvement" provide useful reference and practical examples for the teaching reform of basic engineering courses.

Keywords: Data Structure; Blended Teaching; Results-oriented Education; Combination of Online and Offline

1. Introduction

OBE, also known as outcome-based education, attaches importance to learning output, is learning outcome-oriented, optimizes the teaching implementation process, enhances teaching design through clear learning objectives and evaluation standards, and improves students' learning effectiveness. Online and offline hybrid teaching is a new teaching mode, which is different from the previous teaching mode, which introduces online teaching into the traditional classroom, and the introduction of this new hybrid teaching mode optimizes the allocation of teaching resources, enriches the classroom teaching content, and effectively improves the classroom teaching effect.

With the rapid development of information technology and the profound transformation of higher education models, blended teaching has become an important trend in the global education field, which aims to improve teaching efficiency by integrating online flexibility with offline interactivity. Driven by the professional certification of engineering education, the concept of outcome-oriented education has been deeply integrated into the construction of the curriculum system, emphasizing the reverse teaching design with the final ability of students as the core. In this context, data structures, as the core basic course in the field of computer science, have attracted much attention for their teaching reform. The traditional teaching mode is often centered on teachers and teaching materials and it is difficult to adapt to students' differentiated learning rhythm and in-depth understanding needs. However, early online teaching resources sometimes lack systematic goal guidance, resulting in disconnect between the learning process and the final ability output.

Although the current research has discussed the concept of blended teaching or OBE, the in-depth research on the concept of OBE systematically runs through the whole process of data structure blended teaching and drives the integration of teaching objectives, activities and evaluation. Recent research has mainly focused on the construction of blended teaching models, such as the exploration of blended teaching models in data structure courses by Li and Zhang, or the application of OBE concepts in specific professional courses [1]. International studies have shown that the quality of online interaction in blended learning environments has an important impact on learning outcomes [2]. The study by Wang and Liu also shows that OBE-based curriculum design can significantly improve students' engineering practice ability [3]. In addition, the innovative practice of the integrated teaching model based on the BOPPPS model in computer courses [4] and the application of project-led blended teaching methods in programming courses [5] provide valuable references for this study. Smith et al.'s study found that blended teaching combined with online learning analytics can effectively improve students' learning outcomes in STEM education [6]. Chen and Wang conducted an empirical study on the relationship between online learning behavior and academic performance based on learning analysis techniques [7]. Although these efforts have promoted teaching reform at different levels, they have also highlighted the urgency and innovation space for realizing refined OBE hybrid teaching design in core courses with strong theory and high abstraction such as data structures.

To address the above challenges, this study aims to construct and practice an online and offline hybrid teaching mode of data structure courses based on the concept of OBE. The method first clarifies the ability output goals of the course according to the graduation requirements, and then reverses the teaching content and activities based on this. In the online session, SPOC and other platforms are used to provide micro-lesson videos, algorithm animations and other resources to support students in independent knowledge learning and preliminary practice; The offline classroom has been transformed into in-depth discussion and collaborative exploration based on problem solving and project-driven, focusing on cultivating students' problem analysis, algorithm design and engineering implementation skills. The reform of the teaching evaluation system is a key part, which adopts a combination of process evaluation and final evaluation, and introduces various forms such as programming practice, project reports, and peer evaluation to ensure continuous tracking and multi-dimensional assessment of students' learning outcomes. By systematically integrating the concept of OBE and blended teaching, this study not only hopes to improve the teaching effect and students' comprehensive ability of data structure courses, but also provides a reference scheme and practical basis for the teaching reform of similar engineering basic courses.

2. The Traditional Teaching Status of Data Structure Courses

2.1 Teacher-Centered "Indoctrination" Classroom Teaching

Most traditional data structure teaching follows a linear, teacher-led knowledge transfer model. In the classroom, teachers usually use board books or PPT to systematically explain the logical structure, physical storage structure and corresponding basic operation algorithms of various data structures in the order of the textbook chapters. The advantage of this model lies in the systematicness and efficiency of knowledge transmission, which can cover a large amount of teaching content in limited class hours. However, its drawbacks are also becoming increasingly prominent. The center of the teaching process is the teacher's "speaking", not the students' "learning" and "thinking". Students passively receive information and become "receiving containers" of knowledge, rather than active "meaning builders".

This one-way indoctrination directly leads to a serious lack of student participation. For abstract concepts in data structures (such as pointer operations, recursive processes, graph traversal) and complex algorithms (such as quick sorting, hash conflict resolution, shortest path algorithm), it is difficult for students to form a deep understanding just by listening and taking notes. There is a lack of immediate and interactive feedback mechanism in the classroom, and students' doubts cannot be answered in time, and it is difficult for their thinking to keep up with the rhythm of teachers, which is easy to form the accumulation of knowledge loopholes. In the end, the classroom atmosphere is easy to become dull, students' learning initiative and intrinsic motivation are weakened, and the cognition of the course stays at the level of memorizing formulas and algorithm steps, rather than being used as a powerful tool to solve practical problems.

2.2 There is a Serious Disconnect between

Theoretical Teaching and Practical Application

Another significant problem in the traditional teaching mode is that there is a clear gap between theoretical teaching and hands-on practice. In the classroom, teachers focus on the explanation of algorithm ideas and the theoretical derivation of processes, which is important, but if there is a lack of timely, sufficient and guided programming practice, these theories are like castles in the air. The practical session usually exists in the form of independent and verified experimental courses, which lags behind theoretical teaching in terms of time and content. Students often implement the algorithms learned in the classroom in the experimental class after a few days, at which point the theoretical knowledge may be blurred, and the effect of practice is greatly reduced.

More importantly, these lab questions are often highly abstract and simplified, such as "implementing a binary tree in order" or "implementing a queue with a chain structure". While they can exercise students' basic coding skills, they do not clearly demonstrate the value and application scenarios of these data structures in solving complex engineering problems on a larger scale and with more realistic contexts. Students cannot connect isolated knowledge points to form systematic thinking to solve complex problems. This disconnect leads to the fact that even if students can memorize the time complexity of various sorting algorithms, they still feel at a loss when faced with a practical application problem that requires the comprehensive use of stacks, trees and sorting algorithms to solve, and do not know how to transform theory into effective solutions.

2.3 A Single Rigid Assessment and Evaluation System

Matching the above teaching mode is the traditional single-essential evaluation system with the final closed-book examination as the core. This assessment method is highly dependent on the written test, which focuses on the memory of basic concepts, manual simulation of algorithms, and theoretical calculation of time complexity. Although it can test students' mastery of knowledge points to a certain extent and facilitate standardized judgment, its limitations are also very prominent. First, it does not effectively assess students' core engineering abilities, such as program design, writing, debugging, and testing. A student who scores high on a written test may not even be able to write a complete and working program in actual programming. Secondly, this model of "one test determines the world" ignores the efforts and growth of students throughout the learning process, and cannot reflect the dynamic changes in their learning trajectory. It has given rise to a test-oriented learning strategy, with some students accustomed to rushing recitation before exams rather than continuously engaging and deepening their understanding throughout the semester. This evaluation system not only fails to comprehensively and objectively measure students' learning outcomes, but also solidifies the learning atmosphere of "emphasizing theory, light practice, focusing on results, and neglecting process" because of its reverse guidance effect, which is contrary to the continuous tracking and multi-dimensional ability assessment emphasized by the OBE concept.

2.4 It is Difficult to Take into Account the Differentiated Needs of the Student Group

In the traditional unified teaching model, teachers are faced with a class that is considered a homogeneous whole and the pace and depth of instruction are often determined based on the teacher's experience or assumptions about "average" level students. However, there are objective and significant differences in students' knowledge base, logical thinking ability, programming practical experience, and learning habit style. For students with good foundation and strong abilities, the unified teaching pace may seem slow and the content is not challenging, resulting in their learning potential not being fully stimulated and their interest in learning decreases. On the contrary, for students with a weak foundation and difficulty in follow-up, unified fast-paced teaching may cause them to constantly encounter setbacks, accumulate problems, and eventually choose to give up because it is difficult to overcome difficulties.

Traditional classrooms lack effective mechanisms to implement truly personalized teaching. It is difficult for teachers to grasp the learning status and knowledge blind spots of each student in a timely and accurate manner, and cannot provide targeted tutoring and differentiated learning resources. This "one-size-fits-all" teaching method objectively causes the waste of teaching resources and the polarization of teaching effects, and cannot achieve the educational goal of allowing every student to achieve the greatest development on their original basis.

To sum up, the traditional teaching mode of data structure courses has played an important role in specific historical periods, but its inherent characteristics of "teacher-centered, textbook-centered, and classroom-centered" have increasingly shown its limitations in stimulating students' initiative, promoting ability transformation, implementing scientific evaluation, and meeting personalized development in the context of the new era. The existence of these problems constitutes the fundamental motivation to promote the teaching reform of the course and explore new models such as online and offline hybrid teaching based on OBE.

3. Advantages and Feasibility Analysis

3.1 Theoretical Support and Maturity of Technical Conditions

The construction of this research model has a solid and diverse theoretical foundation. The outcome-oriented education concept provides a top-level design philosophy for the entire teaching model, ensuring that all teaching activities and evaluations are closely centered on the ultimate ability goals that students need to achieve, and realizing the "reverse" and "purpose" of teaching design. Constructivist learning theory emphasizes that learning is the process of students actively constructing meaning in interaction with the environment, which provides a direct theoretical basis for online independent inquiry and offline collaborative learning, and promotes teaching from "knowledge indoctrination" to "situation creation" and "meaning construction". Studies have shown that constructivism-based blended learning environments can significantly improve students' learning engagement and deep learning ability [8]. Bloom's cognitive goal classification theory helps teachers finely distinguish between different cognitive level goals in online and offline links: low-level goals such as memory and comprehension are mainly completed by online links, while high-level goals such as application, analysis, evaluation and creation are left to offline classrooms for in-depth research, so as to achieve optimal allocation of teaching resources and maximize teaching efficiency.

In terms of technical conditions, the in-depth development of education informatization in recent years has provided unprecedented convenience for blended teaching. The rapid development of intelligent teaching systems provides strong support for personalized learning, and AI-based learning analysis technology can monitor students' learning status in real time and provide teachers with accurate teaching intervention basis [9]. Mature online teaching platforms (such as SPOC platform, Moodle, Chaoxing Learning Pass, etc.) provide a stable and reliable technical carrier for this model. These platforms can not only carry multimedia learning resources such as videos, documents, animations, but also integrate a series of teaching management functions such as homework submission, online quizzes, discussion forums, data statistics and analysis, making it possible to push personalized learning paths, collect real-time learning process data, and make it possible to formative evaluation. The emergence of special teaching tools such as algorithm visualization tools and online programming evaluation systems can greatly improve the specificity and feedback timeliness of abstract algorithm learning in data structures. The dual maturity of theory and technology paves the way for the implementation of this study.

3.2 Systematic Reconstruction of Teaching Process under the Guidance of OBE Concept

The core advantage of this model is that it realizes the complete reconstruction of the teaching process of data structure courses through the OBE concept, forming an organic whole that is goal-driven, interlocking and continuous improvement. At the beginning of the course, it is clear to define the specific and measurable competency indicators that students should have after the course (such as "being able to select and design appropriate data structures for specific problems, and demonstrate their strengths and weaknesses"), and these abilities are directly connected to the graduation requirements. Since then, all teaching and learning sessions have been designed to achieve this goal.

In the online session, students no longer passively receive a unified flow of information, but independently plan their learning path based on clear ability goals and under the guidance of the teacher's carefully designed task list. The platform provides micro-lesson videos, algorithm animations, interactive courseware and other resources, allowing students to control their learning progress according to their own situation and consolidate their basic knowledge by repeatedly watching and pausing thinking. Offline classrooms are thus liberated from the one-way impartation of knowledge and completely transformed into a place for deepening and applying abilities. Teachers can design project-based learning tasks based on real-world problems, such as guiding students to compare and analyze the data structures of e-commerce shopping carts and social media friend relationships, and implement prototypes. In this process, students engage in group discussions, scheme design, code writing, and defense, while teachers play the roles of facilitators, coaches, and evaluators, focusing on cultivating students' computational thinking, innovative collaboration, and ability to solve complex engineering problems. This systematic restructuring makes online and offline no longer separate parts, but a unified process that jointly serves the goal of capacity output.

3.3 Realize the Deep Integration of Personalized Learning and Process Evaluation

The most difficult problem of differentiated needs in the traditional teaching mode has been found to be solved in this research model. Online learning platforms naturally have the advantage of supporting personalized learning. The system can record each student's learning trajectory data such as video viewing time, chapter test scores, homework completion, and activity in discussion areas. Based on these data, teachers can accurately identify students with learning difficulties and provide timely early warning and intervention; At the same time, more challenging extended reading materials or programming projects can also be pushed for students who have the ability to learn, so as to achieve personalized guidance of "one student, one strategy".

At the same time, this model has built a diversified process evaluation system throughout, which has completely changed the situation of "one test determines the world". The final score of students is composed of online activity participation, chapter quizzes, programming assignments, offline project performance, group contributions, final project reports and other components. Recent studies have shown that this procedural evaluation system based on learning analysis can effectively predict students' learning outcomes and provide data support for teaching improvement [9]. This multiple evaluation method is not only more fair and comprehensive, but also has a positive guiding effect on students' learning process. It encourages students to distribute their efforts evenly throughout the semester and to stay committed rather than rushing before the exam. Every online quiz, every programming assignment, and every classroom discussion becomes a feedback point for their learning process and a ladder for their ability growth. This closed loop of "learning-practice-feedback-improvement" greatly promotes the development of students' metacognitive ability, enables them to learn to manage their own learning, and truly realizes the functional transformation of teaching evaluation from "proof learning" to "improved learning" [10].

4. Practice and Effect Analysis

4.1 Teaching Practice Implementation Plan

The hybrid teaching mode process shown in Figure 1 constructs a result-oriented dynamic cycle system, which is centered on the spiral of teaching quality through the closed-loop mechanism of "goal setting, process implementation, diagnosis and evaluation, and continuous improvement". The process starts from clear learning outcomes to guide students to carry out online self-directed learning, and the system can diagnose students' learning effectiveness in time and automatically trigger personalized interventions by collecting and analyzing learning behavior data in real time to ensure that every student is not left behind. In the offline seminar, students transform the basic knowledge obtained online into the practical ability of projects to solve practical problems, so as to complete the ability leap from theory to application. The final evaluation and improvement stage compares students' learning outcomes with the set goals, providing data support and decision-making basis for the next round of teaching optimization, and forming a self-improvement and continuous evolution of an organic teaching system.

This study takes two parallel classes of data science and big data technology in a university as the research object to carry out a one-semester teaching practice of data structure courses. The course covers core data structures such as linear tables, stacks and queues, trees and binary trees, graphs, and important algorithms such as sorting and lookup. The experimental class adopts the online and offline hybrid teaching mode based on the OBE concept, and the control class follows the traditional teaching mode of "teacher lecture + on-the-machine experiment". The teaching team first clarified the ability output goals of the course, including being able to analyze the temporal and spatial complexity of different data structures, selecting appropriate data structures for specific problems, implementing basic operations of typical data structures, and using data structures to solve practical problems.

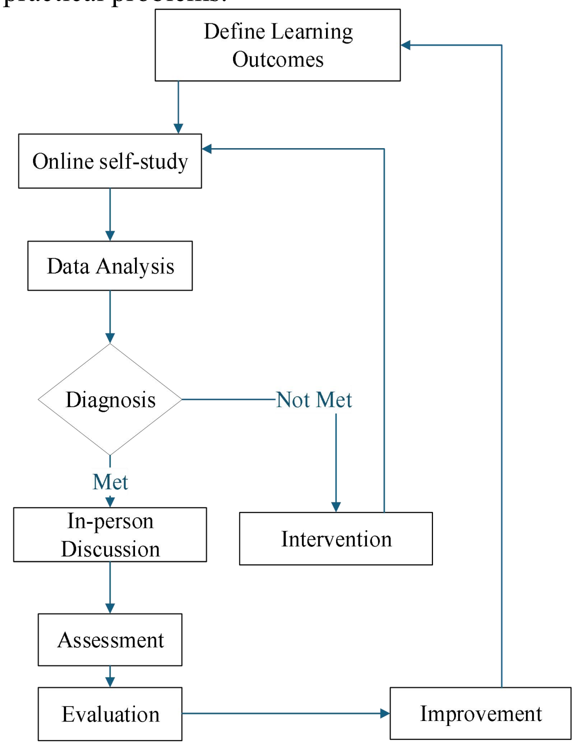

Figure 1. Blended Teaching Mode Process

In terms of online teaching resource construction, a visual demonstration system for algorithm execution process is developed according to the abstract characteristics of data structure. For example, the traversal of binary trees, the breadth-first search and depth-first search of graphs, and the divide-and-conquer process of quick sorting are all made into interactive animations to help students understand the execution details of the algorithm. Online programming platforms provide simple to complex data structure implementation questions, and students can get instant feedback on code execution results. Offline teaching focuses on typical application scenarios, such as using stacks to realize expression evaluation, using graphs and shortest path algorithms to design campus navigation systems, and applying hash tables to implement compiler symbol tables.

4.2 Learning Effect Evaluation Methods

In order to comprehensively evaluate students' mastery of the core knowledge of data structures and the improvement of their abilities, a multi-dimensional evaluation system is established. At the level of basic knowledge, students' understanding of the basic concepts of data structures and algorithm principles is assessed through a unified final exam. At the level of practical ability, students' programming ability and algorithm application ability are evaluated through course projects. At the level of innovation ability, students' algorithm design ability is evaluated through the solution of open-ended problems.

The specific evaluation methods include: programming questions require students to write implementation code for specific data structures on the spot; Algorithm analysis questions examine students' understanding of the performance characteristics of different data structures. Project reports assess students' ability to solve complex problems using data structures. For example, in the Hash Table-Based Dictionary Implementation project, the evaluation focused on the selection of conflict resolution strategies, the control of load factors, and measures for performance optimization. At the same time, data such as the time students complete programming exercises, the number of code submissions, and the debugging process are collected through the online learning platform to analyze students' learning behavior and difficulties.

4.3 Analysis of Teaching Effect

Through one semester of teaching practice, the experimental class demonstrated significant advantages in all assessment indicators of the data structure course (Table 1). Regarding mastery of fundamental knowledge, the experimental class scored 18.2% higher than the control class on problems testing algorithm design and analysis skills. In terms of understanding complex data structures such as binary trees and graphs, the students in the experimental class showed a deeper understanding.

Table 1. Comparative Analysis of Teaching Effectiveness of Data Structures Course

Evaluate the Dimensions	Experimental group	Control group	Enhancement range
Mastering basic knowledge			
Algorithm design problem score rate	82.4%	64.2%	+18.2%
Understanding of Trees and Binary Trees	88.3%	70.1%	+18.2%
Level of understanding of graph structure	85.7%	67.5%	+18.2%
Practical ability performance			
Campus navigation system implementation rate	87.0%	65.0%	+22.0%
Performance in learning process			
Online discussion participation	92.0%	65.0%	+27.0%
Improve self-learning ability	92.0%	75.0%	+17.0%
Enhancing the depth of knowledge understanding	88.0%	70.0%	+18.0%

In terms of practical ability, the experimental class students performed particularly well in course projects. In the "Campus Navigation System" project, 87% of the students in the experimental class were able to correctly apply the graph data structure and reasonably choose the shortest path algorithm, while the proportion in the control class was only 65%, demonstrating stronger engineering practice capabilities. The learning behavior data showed that the proportion of knowledge mastered by the experimental class students was still higher than that of the control class, indicating that their programming ability was effectively improved.

5. Conclusion

Based on the OBE concept, this study constructs an online and offline hybrid teaching mode of data structure course, and verifies its effectiveness through one semester of teaching practice. This model takes student ability as the core, and realizes the fundamental transformation from "teacher-centered" to "student-centered" by clarifying curriculum objectives, reconstructing teaching content, innovating teaching methods, and reforming the evaluation system. The results show that this model significantly improves students' learning effect in data structure courses, especially in algorithm design ability, engineering practice ability, and innovative thinking ability. The teaching practice data show that the experimental class is significantly better than the control class in the traditional teaching mode in terms of basic knowledge mastery, project practice ability and learning process performance.

The value of this study is not only to provide an actionable blended teaching scheme for the data structure course, but more importantly, to construct a result-oriented and student-centered teaching paradigm. Through systematic teaching design, this paradigm effectively solves the problems of disconnection between theory and practice, single evaluation method, and difficulty in meeting individual needs in traditional teaching. Its methodology of "goal guidance-reverse design-continuous improvement" has important reference value for the teaching reform of similar engineering basic courses. In the future, we will further improve the hierarchical teaching mechanism, optimize the connection between online and offline teaching links, strengthen the application of learning and analysis technology, continue to promote the improvement of teaching quality, and provide strong support for cultivating computer professionals with innovation ability and engineering practice ability.

Acknowledgments

This paper was supported in part by 2024 Experimental Teaching Research and Reform Program at Liaocheng University (No.SY2024204), the System Development of ERP for Energy-Saving and Consumption Reducing Enterprise Management of Production Lines (No.318/K25LD57), and the Smart Community Software Development (No. 318/K25LD56).

References

[1] Li Fang, Zhang Ming. Exploration of Blended Teaching Mode of Data Structure Course. Computer Education, 2023, 21(5): 45-49.
[2] Smith J, Johnson M. Enhancing Student Engagement in Blended Learning Environments. Computers & Education, 2022, 185: 104541.
[3] Wang Wei, Liu Yang. Design and Practice of Computer Courses Based on OBE. Research in Higher Engineering Education, 2022, 40(3): 78-82.

[4] Chen Jing, Li Qiang. Teaching Reform of Computer Basic Courses Based on BOPPTS Model. Experimental Technology and Management, 2024, 41(1): 56-60.
[5] Zhao Ming, Zhou Li. Research on the Application of Project-Guided Blended Teaching in Programming Courses. Modern Educational Technology, 2023, 33(2): 89-94.
[6] Smith J, Anderson M, Brown L. Learning Analytics in Blended Learning Environments for STEM Education. Journal of Educational Technology & Society, 2023, 26(1): 145-158.
[7] Chen Hua, Wang Lei. Research on the Relationship between Online Learning Behavior and Academic Performance Based on Learning Analysis. Research of Open Education, 2024, 30(1): 112-120.
[8] Li Ming, Wang Xiaohong. Research on the Influence of Constructivism-based Blended Learning Model on Students' Deep Learning. Modern Educational Technology, 2024, 34(1): 45-52.
[9] Zhang Hua, Liu Wei. Artificial Intelligence-Enabled Learning Analysis and Precision Teaching Intervention Model Construction. Journal of Electronic Education Research, 2024, 45(2): 78-85.
[10] Wu, Chaoqun. "Effect of online and offline blended teaching of college English based on data mining algorithm." Journal of information & knowledge management, 21 Supp02 (2022): 2240023.