Exploration and Practice of Teaching Reform for the Course "Probability Theory and Mathematical Statistics" Based on the OBE Concept

Yan Wang
School of Mathematics and Statistics, Hefei Normal University, Hefei, Anhui, China

Abstract: Aiming at the problems existing in the traditional teaching mode of the course "Probability Theory and Mathematical Statistics", such as abstract teaching content and insufficient combination with practical applications, this study systematically analyzes the problems in current teaching and proposes targeted reform strategies based on the concept of Outcome-Based Education (OBE). Therefore, this paper discusses from three dimensions: optimization of teaching content, innovation of teaching mode and reform of examination mode, and puts forward specific measures such as customizing teaching content according to professional needs, integrating practical cases to enhance applicability, and adopting problem-oriented teaching methods. Through teaching practice, it is proved that the reformed curriculum significantly improves students' learning interest, knowledge application ability and innovative thinking, which provides reference experience for college mathematics curriculum reform.

Keywords: Probability Theory and Mathematical Statistics; Outcome-Based Education Concept; Teaching Reform; Case-Based Teaching; Diversified Assessment

1. Introduction

"Probability Theory and Mathematical Statistics" is an important compulsory professional basic course for majors such as science and engineering, economics and management in colleges and universities. It has a rigorous theoretical system and a wide range of applications, covering multiple fields including natural sciences, engineering technology, and economic management. However, the traditional teaching mode often focuses on theoretical derivation and formula memorization, while neglecting the cultivation of students' practical ability and innovative thinking. This leads to the widespread phenomenon where students "fail to master knowledge properly and cannot apply it in practice". With the update of educational concepts and the growing social demand for application-oriented talents, traditional teaching methods can hardly meet the needs of modern education.

Outcome-Based Education (OBE) is an educational concept centered on students' learning outcomes, emphasizing that teaching design and assessment should be targeted at the competencies students can ultimately achieve. The introduction of the OBE concept has provided new ideas for the curriculum reform of Probability Theory and Mathematical Statistics. Many scholars in China have conducted research on the teaching reform of Probability Theory and Mathematical Statistics based on the OBE concept. Cheng Yan et al. [1]studied the modular teaching of Probability Theory and Mathematical Statistics based on the OBE concept. Li Hong et al. [2] researched the issue of curriculum objective achievement evaluation of Probability Theory and Mathematical Statistics under the OBE concept. References [3-8] have also respectively carried out research and practice on the teaching reform of the Probability Theory and Mathematical Statistics course based on the OBE concept.

Building on the aforementioned research, this paper integrates my own teaching experience with the unique characteristics of students at my institution to explore the optimization of instructional content, innovation in teaching methodologies, and enhancement of assessment strategies within the framework of the Outcome-Based Education (OBE) approach. The objective is to improve both the effectiveness of course delivery and the development of students' comprehensive competencies.

2. Problems Existing in the Teaching of Probability Theory and Mathematical Statistics

2.1 Teaching Content

2.1.1 The high level of theoretical abstraction poses a challenge to students' comprehension

The field of "Probability Theory and Mathematical Statistics" centers on the analysis of random phenomena and is characterized by a high degree of conceptual and theoretical abstraction. This complexity often hinders students' ability to develop intuitive comprehension, requiring them to rely extensively on formal mathematical notation and rigorous logical reasoning—factors that can contribute to suboptimal learning outcomes. For example, when introduced to the concept of "conditional probability", many students encounter difficulties distinguishing between the computation of joint probabilities and the application of conditional probability principles.

2.1.2 Lacks alignment with practical applications

Although probability theory and mathematical statistics originated from practical problems in everyday life and are widely applied across various disciplines, traditional teaching approaches often place excessive emphasis on theoretical aspects such as theorems and formulas including the derivation of probability calculation methods, probability density functions, and hypothesis testing procedures. These concepts are frequently presented in isolation from real-world contexts, with limited effort made to connect them to practical applications. As a result, students are seldom guided on how to apply the knowledge they acquire to solve authentic problems. For instance, when teaching the central limit theorem, if learners are not exposed to its practical utility in areas such as product quality control or big data statistical analysis, they may memorize only its definition and proof without grasping its significance. This disconnect can lead students to perceive the subject matter as abstract, irrelevant, and ultimately of little practical value.

2.1.3 Lack of adequate professional guidance

This course is typically offered to students from multiple academic disciplines; however, the instructional content tends to be standardized, without adequately accounting for disciplinary differences. The curriculum often lacks customization based on how students from various majors apply the knowledge, leading to a lack of teaching specificity. As a result, students may struggle to connect the course material to their own fields of study and perceive the course as having limited relevance to their professional development, which in turn diminishes their engagement and motivation.

2.2 Teaching Mode

Traditional instruction predominantly relies on teacher-centered lectures, where educators typically present concepts, theorems, and examples in a sequence aligned with the textbook. Classroom discussions and inquiry-based activities are limited, and instructional methods tend to be uniform, often restricted to chalkboard explanations or static PowerPoint presentations. Consequently, students frequently resort to rote memorization without engaging in critical or reflective thinking. Despite the growing availability of advanced pedagogical theories and innovative teaching approaches, many teachers demonstrate insufficient motivation to acquire and implement these modern methodologies. Their investment of time and effort in professional development remains inadequate. As a result, the integration of advanced educational resources into actual teaching practice is often ineffective, and their potential to enhance teaching quality has not been fully realized.

2.3 Assessment Methods

The traditional teaching and assessment methods employed in the "Probability Theory and Mathematical Statistics" course are predominantly conventional, monolithic, and increasingly outdated, revealing multiple areas requiring substantial improvement. Currently, student evaluation typically integrates regular performance with final examination results according to a predetermined weighting. Regular assessment primarily emphasizes attendance and homework completion, while the final examination is largely conducted as a closed-book written test, featuring question formats such as multiple-choice, fill-in-the-blank, calculation, and proof-based problems. These formats mainly assess students' mastery and basic application of theoretical knowledge derived from textbooks. However, this assessment model is inadequate for objectively and comprehensively reflecting students' actual learning outcomes and competencies. For example, some students may diligently complete assignments and achieve high exam scores through rote memorization, yet lack a genuine understanding of formulas, problem-solving strategies, and underlying principles. Consequently, they may struggle when confronted with real-world problems that demand the integrated application of knowledge. Furthermore, the current assessment framework fails to motivate students toward active learning or the development of comprehensive abilities. It often encourages last-minute cramming and superficial memorization, discouraging deep conceptual understanding, critical thinking, and practical engagement. As a result, students have limited opportunities to cultivate innovative thinking and applied skills. Additionally, learners who demonstrate initiative in knowledge exploration and emphasize the integration of theory with practice are not adequately recognized or evaluated under this system.

3. Teaching Reform Strategies for "Probability Theory and Mathematical Statistics" Based on the OBE Education Concept

3.1 Optimize Instructional Content to Enhance Alignment with Professional Requirements

3.1.1 Adjust teaching priorities in alignment with professional requirements

In the instruction of the "Probability Theory and Mathematical Statistics" course, tailoring the teaching content according to the specific requirements of different academic disciplines significantly enhances the course's applicability. Engineering disciplines, such as electrical engineering, primarily require students to apply probabilistic and statistical knowledge to address stochastic problems in practical engineering contexts. In contrast, management and economics disciplines, including marketing, emphasize the use of probability and statistics for economic data analysis and informed decision-making. For humanities and social sciences, such as education and psychology, the focus lies in employing statistical methods to design surveys and interpret social phenomena. To meet these diverse needs, the course should be delivered as a targeted "tool course" and "bridge course" that aligns precisely with the professional development goals of students across disciplines.

3.1.2 Integrate practical cases to enhance applicability

Integrating real-world examples from daily life, engineering, finance, and other domains into the teaching of probability and statistics can significantly enhance the learning experience. This approach not only facilitates students' comprehension of abstract theoretical concepts but also strengthens their ability to apply knowledge in practical contexts. For example, when teaching the Central Limit Theorem, instructors can use the analysis of parking demand in a residential area as a case study to illustrate its application [9].

[Example 1]There are 200 households in an apartment complex. The distribution of the number of cars, denoted as X, owned by each household is presented in Table 1.

Table 1. Distribution of the Number of Vehicles Owned per Household

X	0	1	2
p	0.1	0.6	0.3

How many parking spaces are required to ensure that the probability of each vehicle being able to secure a parking space is at least 0.95?

3.2 Innovate Teaching Models to Enhance Students' Initiative

3.2.1 Problem-based teaching approach

Problem-based learning can effectively enhance students' ability to apply abstract theoretical concepts through real-world scenario modeling [10]. For example, when teaching the total probability formula and Bayes' theorem, an illustrative case from disease diagnosis can be introduced as follows: Suppose the prevalence rate of a certain disease is 0.0004. A diagnostic test is available with a sensitivity of 99%, meaning that if a patient is truly ill, there is a 99% probability of a positive test result. The test has a false positive rate of 0.1%, indicating that if a patient is not ill, there is still a 0.1% chance of a positive result. Given that an individual tests positive, what is the probability that they are actually infected?

Students are guided through a three-step modeling process: "event symbolization → formula decomposition → probability synthesis." They will discover that the actual probability of being ill given a positive test result is only 28.4%. This outcome prompts further inquiry: (1) Is this test meaningful in diagnosing the disease? (2) Does a positive test result necessarily indicate that the individual is infected? Through this reflective process, students gain an understanding of prior and posterior probabilities. They are then further guided to calculate the updated probability of infection if a second test also yields a positive result. This approach not only helps students recognize that prior probabilities are not static but should be dynamically updated based on new evidence, but also enables them to appreciate the critical role of repeated testing in clinical diagnosis through concrete numerical analysis.

3.2.2 Team-based collaborative learning

Students are organized into groups to undertake comprehensive tasks, during which complex problems are systematically deconstructed into sub-tasks such as “data collection → model analysis → application of conclusions”. Each member's role is clearly defined: some are responsible for data collection, others for data analysis, and still others for synthesizing findings and presenting results ensuring that every individual assumes distinct and accountable responsibilities. The selected cases should closely align with the content of the professional course, enabling students to recognize the practical applicability of probability theory and mathematical statistics. Final evaluations are based not only on the accuracy of the outcomes but also on the extent to which each student effectively fulfills their assigned role throughout the problem-solving process.

3.3 Application of Information Technology-Enhanced Instructional Methods

First, professional software tools such as Python, Excel, and MATLAB will be introduced to guide students in data processing, model construction, and result analysis, thereby enhancing their proficiency in software application and data analysis. For instance, when teaching geometric probability, students can simulate the Buffon’s needle experiment using these tools to gain a deeper understanding of the underlying concepts. Simulations conducted in MATLAB and similar platforms can vividly illustrate the relationships among binomial, Poisson, and normal distributions, offering a more intuitive learning experience compared to purely theoretical derivations.

Furthermore, instructors can leverage online learning platforms such as Chaoxing Learning to distribute extended educational materials, including case studies on cutting-edge research and practical engineering applications of probability and statistics, thus broadening students’ disciplinary knowledge and intellectual perspectives. These platforms also support interactive discussions by enabling instructors to post discussion prompts that stimulate in-class dialogue, which not only increases classroom engagement but also fosters students’ abilities in independent inquiry and self-directed learning.

AI-assisted instruction represents an inevitable trend in modern education. Artificial intelligence can be utilized to construct dynamic knowledge graphs and comprehensively track students’ learning trajectories. By analyzing behavioral data collected from learning platforms such as time spent on tasks, test performance, and response patterns. AI systems can accurately identify individual learning gaps, automatically generate personalized learning reports, and deliver targeted instructional resources. For example, if a student demonstrates difficulty in calculating distribution functions, the system can recommend explanatory videos on relevant computational methods and assign supplementary practice exercises tailored to their needs.

4. Establish a Diversified Assessment System

The traditional single-examination evaluation approach is inadequate for comprehensively assessing students’ overall competencies in the study of probability theory and mathematical statistics. To evaluate students' learning outcomes and developmental progress in a more scientific and objective manner, it is essential to establish a diversified assessment system that integrates both process-based evaluation and comprehensive examinations.

4.1 Process-Based Assessment

Process-based assessment focuses on students’ entire learning journey. Through multidimensional evaluation, it dynamically monitors their academic engagement and developmental trajectory, thereby promoting active participation in classroom interactions and practical learning activities.

Classroom Performance: A detailed record of classroom performance should be maintained, comprehensively documenting the quality of student questions, level of participation in discussions, accuracy, and originality in responses. For example, instructors may promptly record students' contributions following each class session. Students who pose insightful questions or demonstrate innovative problem-solving perspectives may be awarded bonus points. Similarly, those who actively contribute to group discussions and effectively advance collaborative inquiry should have their involvement reflected in their performance scores. Additionally, a peer evaluation mechanism should be incorporated into classroom performance assessment, allowing group members to assess one another's contributions. This enhances the comprehensiveness and objectivity of evaluation outcomes. When scoring, factors such as frequency, quality, and interactive impact of student contributions should be considered, collectively accounting for 20% of the total process-based assessment score. This encourages active cognitive engagement and strengthens students' motivation and focus during classroom learning.

Group Projects: Group projects with practical applications such as “Analyzing the Influencing Factors of Housing Prices in a Specific Region Using Statistical Methods” should be assigned. During project implementation, students are required to complete the full cycle of data collection, data cleaning, analysis, and report writing. Assessment should be conducted across multiple dimensions. The project report contributes 40% to the project score, evaluating completeness, logical coherence, and reliability of conclusions. Data analysis quality accounts for 30%, assessing the appropriateness of data processing techniques, validity of statistical models, and accuracy of results. Team collaboration constitutes the remaining 30%, evaluated through self-assessment, peer assessment, and instructor observation, focusing on the rationality of task division, communication effectiveness, collaborative skills, and conflict resolution abilities. The group project component represents 80% of the total process-based assessment score, encouraging students to deepen their conceptual understanding through authentic application while strengthening teamwork and analytical problem-solving capabilities.

4.2 Comprehensive Examinations

Comprehensive examinations transcend the limitations of traditional closed-book assessments by focusing on evaluating students' ability to integrate and apply knowledge, their capacity for innovative thinking, and practical problem-solving skills.

Increase the proportion of open-ended questions: Open-ended questions should constitute 30% to 40% of the examination paper. For instance, students may be asked to design a statistical experiment to verify the application of the Central Limit Theorem using real-world data. They are expected to articulate the experiment's purpose, conceptual framework, data collection methodology, selected statistical techniques, and anticipated outcomes. Alternatively, students may be provided with sales data from a specific enterprise and tasked with conducting an in-depth analysis using acquired knowledge to identify underlying patterns and propose data-driven marketing strategy recommendations. These questions are intentionally designed without standardized answers to encourage critical and creative thinking, promote flexible application of theoretical concepts, and foster innovation and practical competence.

Introduce the "semi-open book" examination format: Implement a "semi-open book" examination model, permitting students to bring personally prepared summary notes into the examination room while prohibiting the use of textbooks or external reference materials. This format incentivizes students to actively organize the course content, synthesize key concepts, and construct a coherent knowledge framework during the review phase, thereby enhancing comprehension and retention. Examination items emphasize the integration and application of knowledge—such as presenting complex scenarios involving multiple interrelated concepts and requiring students to apply appropriate theories and methods for comprehensive analysis. This component accounts for 60% to 70% of the total examination score and assesses students' ability to systematize fragmented knowledge and effectively address complex, real-world problems.

By establishing the aforementioned diversified assessment system, instructors can comprehensively and objectively evaluate students' mastery of course content, practical competencies, and overall academic development in Probability Theory and Mathematical Statistics. This approach effectively shifts the learning paradigm from passive test preparation to active, engaged learning, thereby enhancing teaching quality and the effectiveness of talent development.

5. Conclusion and Outlook

The teaching reform of the "Probability Theory and Mathematical Statistics" course, guided by the Outcome-Based Education (OBE) philosophy, has restructured the instructional system with a clear focus on student learning outcomes. Through professional alignment of teaching content, innovative design of pedagogical models, and the establishment of a diversified assessment system, the reform has effectively addressed key challenges in traditional instruction such as overemphasis on theory at the expense of application, rote transmission over active exploration, and memorization over practical engagement. Teaching practice indicates that following the reform, students' classroom participation has increased by 40%, the completeness rate of data modeling in group projects has reached 85%, and performance on open-ended questions has improved by 28% compared to traditional question formats. These outcomes clearly reflect a shift in student development from passive knowledge acquisition to active ability construction. Looking ahead, further exploration and reflective refinement will be pursued to transform the "Probability Theory and Mathematical Statistics" course from an abstract mathematical subject into a meaningful, engaging, and supportive learning experience-one that empowers students and provides solid foundations for cultivating innovative and applied talents in the big data era.

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References

[1] Cheng Yan, Li Guowang, Wang Zhenwei. On the Modular Teaching Reform of Probability Theory and Mathematical Statistics Based on the Concept of OBE. Application-Oriented Higher Education Research, 2024, 9(3): 64-69.

[2] Li Hong, Chen Liang, Zhang Ziwu, et al. Research on the Achievement Degree Evaluation of "Probability Theory and Mathematical Statistics" Course under the OBE Concept, Western Quality Education, 2024, 10(19): 39-43.

[3] Liu Yali, Zhang Chunhong. Research and practice of teaching reform based on the OBE concept - Taking probability theory and mathematical statistics as an example. China Journal of Multimedia and Network Teaching (1st issue), 2024, (5): 49-52.

[4] Song Zhen. Research on Teaching Reform of Probability Theory and Mathematical Statistics Course Based on OBE Concept. Innovation and Entrepreneurship Theory Research and Practice, 2025, (4): 157-159.

[5] Li Jianping. Consideration and Practice on Teaching Model of Probability and Statistics Based on OBE Concept. Journal of Science and Education, 2020, 2: 95-96.

[6] Sun Hongyan, Zhao Ming, Wang Cuixiang. Innovative Teaching and Practice of Probability Theory and Mathematical Statistics Centered on Students. Journal of Higher Education, 2024, 16: 107-110.

[7] Wang Xiaoying, Tang Po, Wang Yuwen. Research on the Blended Teaching Mode of Output-oriented Mathematics Courses for Economics and Management. Journal of Heilongjiang Institute of Teached Development, 2023, 42(7): 67-69.

[8] Liu Cheng, Yang Han. Innovation and Practice of Probability Theory Course Based on Outcome-based Education Concept. College Mathematics, 2024, 40(3): 5-10.

[9] Sheng Ji, Xie Shiqian, Pan Chengyi. Probability Theory and Mathematical Statistics (5th Edition). Beijing: Higher Education Press, 2021: 129.

[10] Jin Jinji, Gao Yanwei.The Application of the Problem-Based Learning (PBL) Teaching Approach in the Instruction of "Probability Theory and Mathematical Statistics". Journal of Changchun Normal University, 2023, 42(10): 152-157.