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Innovative Practice of Advanced Mathematics Teaching Mode in Private Colleges from the Perspective of Double-innovation Education

Ying Xu[1,a,*]

[1]*Foundation Department, The Tourism College of Changchun University, Changchun, Jilin, China*
[a]*136825018@qq.com*
[*]*Corresponding author*

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Abstract: Nowadays, innovation and entrepreneurship education is developing rapidly, the traditional teaching mode is facing new challenges and reform needs. This study takes "Advanced Mathematics" course in private colleges as the object, and discusses how to innovate the teaching mode from the perspective of "double innovation education". The research adopts a combination of qualitative and quantitative methods. In this paper, we first collect data through questionnaires and interviews to analyze the current teaching status and problems of higher mathematics courses in private colleges and universities; second, this paper designs and implements a pilot teaching reform based on the theories of Problem-Based Learning (PBL) and Student-Centered Learning (SCL) to assess the effectiveness of the reform measures by comparing the learning effectiveness of the students in the experimental group and the control group. The score of students' technical application gradually increased from 75 points in the first week to 96.5 points in the 15th week. The study found that integrating the concept of "double innovation education" into higher mathematics teaching can not only enhance students' learning interest and autonomous learning ability, but also significantly improve their innovative thinking and problem-solving ability. Therefore, innovative teaching mode is of great value to improve the comprehensive quality and innovative ability of students in private colleges and universities, and is helpful to cultivate high-quality talents that meet the needs of modern economic and social development.

1. Introduction

With the rapid development of global economy and the continuous progress of science and technology, innovation and entrepreneurship education (referred to as "dual-innovation education") is regarded as an important force to promote economic growth and social development. Especially in the field of higher education, the popularization of this concept has become a key way to improve students' innovative ability and practical ability. In view of the unique educational environment and resource allocation of private colleges and universities, how to effectively integrate the concept of "double innovation education" and optimize the traditional teaching mode of higher mathematics has become an urgent problem to be solved. In recent years, although the relevant research is increasing, it is mostly concentrated in public universities, and the specific practice and teaching strategies of private universities are relatively few. Therefore, the purpose of this study is to fill this gap and explore the innovation of teaching mode of "Advanced Mathematics" course in private colleges from the perspective of "double innovation education" through concrete empirical analysis.

Firstly, this study combs the current situation and main problems of higher mathematics courses in private colleges and universities in detail through the combination of literature review and field investigation. Subsequently, a set of teaching reform scheme based on Project-Based Learning (PBL) and Student-Centered Learning (SCL) is designed and implemented, aiming at enhancing students' problem-solving ability and innovative thinking through practical operation and project implementation. In this study, comparative analysis was used to compare the learning effects of students in the experimental group and the control group, so as to verify the actual effect of the reform measures. Through this series of research, this paper not only explores a new teaching mode, but also provides theoretical and practical support for the in-depth implementation of "double innovation education" in private colleges.

This paper has a rigorous structure and clear organization: firstly, it deeply analyzes the research background and theoretical basis, aiming at clarifying the urgent need and value of this study. Subsequently, the research methods and experimental design framework adopted are elaborated in detail, and the careful selection of samples, the comprehensiveness of data collection and the scientific processing flow are explained in detail. The last part focuses on the display of research results. Through the careful comparison of the data of the experimental group and the control group, the actual effect of the teaching mode reform is deeply analyzed, and a series of specific and targeted teaching optimization suggestions are put forward accordingly.

2. Related Work

As a basic course for science and engineering students, advanced mathematics plays a vital role in cultivating students' abstract thinking ability and solving complex problems. Nowadays, scholars began to explore the integration of innovative education concepts into higher mathematics teaching, so as to enhance students' innovative ability and practical application ability. Zhang Wenli discussed the teaching strategy of implementing the problem-driven teaching mode, the principle of problem setting, and the role of modern information technology and teacher guidance in problem-driven. Finally, through specific lesson plans, he explained that in the teaching of advanced mathematics, effective problems were the external driving force to drive students to learn [1]. Chen Guo analyzed the shortcomings of traditional teaching methods in advanced mathematics teaching and the fact that mixed teaching can promote the quality of teaching and learning, and analyzed the steps of adding "rain classroom" mixed teaching to traditional teaching mode, as well as some points to be paid attention to [2]. Fan Haixia believes that information technology has gradually become an important auxiliary tool for education and teaching, enhance students' learning motivation for knowledge, and improve students' satisfaction with higher mathematics teaching classes [3]. Quan Tingting believes that advanced mathematics plays an important role in the training of engineering talents, and the deepening of new engineering construction puts forward new requirements for engineering talents' mathematical basic ability and mathematical application ability. The traditional teaching mode of advanced mathematics is difficult to meet the requirements of training new engineering talents, and it is urgent to reform and innovate the teaching mode [4]. Cevikbas M thinks that flipping classroom can be regarded as a reform-oriented mathematics teaching method [5]. However, the existing research mostly focuses on theoretical discussion and model construction, and lacks empirical research and long-term follow-up evaluation for private colleges and universities in a specific environment.

Numerous studies have proved that innovative teaching methods such as problem-based learning (PBL) can significantly enhance students' learning motivation and participation. During the blockade of COVID-19, Drijvers P conducted distance mathematics teaching in Flanders and Holland, and explored an active teaching mode [6]. Lindsay systematically reviewed the research literature, and gave the results of model exploration in college mathematics education [7]. Thurm D believes that teachers' self-efficacy belief, epistemological belief and technical teaching belief are regarded as the key factors of technical teaching mathematics [8]. Nabayra J's research aimed to describe the experience of non-mathematics freshmen in learning mathematics by using videos made by teachers uploaded to YouTube under the new normal. This virtual existence of teachers facilitates the smooth progress of mathematics teaching [9]. Scull J explored the innovative new model of teacher education in COVID-19 period from the perspective of Australian literature [10]. Jiang Y studied the relationship between college students' entrepreneurial intention and the quality of innovation and entrepreneurship practice teaching [11]. However, these studies often ignore the change of teachers' role and the establishment of students' feedback mechanism, especially in the application scenarios of private colleges and universities. The lack of these factors may lead to the unsatisfactory effect of teaching reform.

3. Method

3.1. Innovative Design and Implementation of Teaching Mode

3.1.1. Preliminary Design of Teaching Mode

First of all, according to the characteristics and needs of students in private universities, a set of teaching scheme combining problem-based learning (PBL) and student-centered learning (SCL) is designed [12-13]. Before the implementation, we conducted special training for the teachers who participated in this study through teachers' lectures, seminars and workshops to ensure that they can understand and master the core concepts and operation methods of the new teaching model.

The concept of entropy is used to evaluate the complexity of learning materials.

$$H(X) = -\sum_{i=1}^{n} P(x_i) \log P(x_i) \quad (1)$$

Here, entropy $H(X)$ is used to measure the uncertainty and complexity of learning content.

3.1.2. The Specific implementation of Teaching Content

(1) Integration of problem oriented learning: designing cases with real-world problems as the background, so that students can cultivate the ability of problem discovery and problem solving in the process of solving mathematical problems. For example, by introducing engineering optimization problems, let students explore how to use mathematical tools for cost-benefit analysis; the design of each case contains clear learning objectives, learning activities and expected results to ensure that students can learn and apply advanced mathematics knowledge in practice.

(2) Strengthening group cooperative learning: promoting students to form cooperative groups, advocate collective wisdom collision, and jointly explore and solve mathematical problems. Each group needs to integrate their ideas, submit solutions, and write reflection reports to deepen their understanding of Student Centered Learning (SCL) [14]; regularly arranging the presentation and defense sessions between groups, aiming at training students' communication skills and teamwork ability, and at the same time, with the help of peer evaluation and feedback, promoting knowledge

absorption and thinking expansion.

(3) Technology-enabled learning experience: advanced mathematical modeling software and programming language are integrated to provide students with powerful tool support, making the process of solving mathematical problems more intuitive and efficient; through practice-oriented project learning, students can not only put theoretical knowledge into practice, but also significantly improve their ability to cope with complex mathematical challenges in the process of solving practical problems.

Linear regression model is used to analyze the relationship between learning effectiveness and learning time [15]:

$$y = \beta_0 + \beta_1 x + \epsilon \tag{2}$$

Among them, y represents the learning effect and x is the learning time, β_0 and β_1 are regression coefficients, while ϵ is the error term.

3.1.3. Establishment of Teaching Evaluation and Feedback Mechanism

This study has carefully constructed a comprehensive evaluation framework, covering the dual dimensions of form and content:

(1) Formal evaluation level

Implementing a comparative test from the beginning to the end of the course to quantitatively evaluate the concrete progress of students in mastering mathematical knowledge and improving their skills; designing a questionnaire on students' satisfaction with learning experience, and directly obtain students' acceptance and valuable feedback on the new teaching mode.

(2) Content evaluation dimensions

Relying on daily classroom interaction and homework evaluation, carefully examine students' learning progress and knowledge mastery quality; introducing the final project exhibition, focusing on evaluating students' innovative thinking, practical operation and ability to solve complex mathematical problems.

(3) Construction of feedback and adjustment mechanism

Setting up immediate feedback channels to ensure that teachers can quickly respond to changes in students' learning status and flexibly adjust teaching programs and contents.

Holding regular teacher-student exchange meetings to gather students' voices as a direct basis for continuously optimizing teaching strategies and contents.

Probability density function is used to simulate the probability of students mastering new concepts;

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \tag{3}$$

Here, x means the students' test scores, μ and σ are the average and standard deviation of the scores respectively.

3.2. The Relationship between Teaching Mode and Intelligent Decision-Making

By constructing an efficient prediction model, we can evaluate students' learning effectiveness in a forward-looking way, so that teachers can keenly catch potential learning challengers, so as to tailor counseling programs and resource support for them in time, and ensure that each student's growth path can get just the right help. In addition, intelligent decision-making technology also empowers teachers to play a key role in the continuous optimization of teaching content and methods, accurately adjust teaching strategies through data analysis and feedback, ensure that teaching activities are targeted and maintain efficient operation, and further improve teaching quality and efficiency.

Information gain is used to evaluate the effectiveness of teaching methods:

$$\mathrm{IG(T,a)} = \mathrm{H(T)} - \sum_{\mathrm{v \in Values(a)}} \frac{|\mathrm{T_v}|}{|\mathrm{T}|} \mathrm{H(T_v)} \quad (4)$$

In this formula, IG represents the information gain, $H(T)$ is the entropy of the target variable, T_v is a subset of value a under the feature v, and $|T_v|/|T|$ is the weight.

Teaching strategy: Introducing eigenvalues and eigenvectors to explain Principal Component Analysis (PCA). Let students practice how to use PCA to reduce the data dimension and improve the analysis efficiency through the actual data set.

4. Results and Discussion

4.1. Experimental Design Refinement and Environmental Parameter Setting

The experiment was carried out in the advanced mathematics course of private colleges and universities, covering two semesters of teaching cycle. 300 students were randomly assigned to six different teaching groups, with 50 students in each group. Each group adopts different teaching strategies to comprehensively evaluate the effect of the teaching model. The main parameters of the experiment include academic performance, student participation, innovation ability evaluation, problem-solving ability test, student satisfaction survey and team cooperation effect evaluation. The experimental data were collected through classroom observation, learning management system records and comprehensive evaluation at the end of the semester.

In this mode, students need to complete a semester's mathematical model innovation project under the guidance of teachers, so as to evaluate their comprehensive application ability. Evaluation index and calculation method: academic performance: students' knowledge mastery is evaluated through the results of mid-term and final exams, and the results are directly reflected by the original scores; student participation: quantified by classroom interaction frequency and activity statistics of online learning platform, with data provided by learning management system; evaluation of innovation ability: based on the performance of students in innovative projects and the final project evaluation results, three independent judges will score and take the average; problem-solving ability test: designing a specific mathematical problem-solving test to analyze students' ability to solve complex mathematical problems.

4.2. Result Analysis

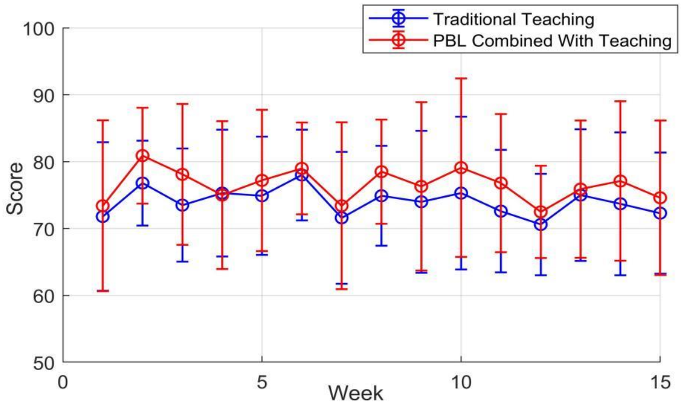

Figure 1: The influence of course weeks on academic performance

(1) Experiment 1: Combination of traditional teaching and PBL

We collected the data of students' academic performance in the experiment, and hoped to analyze how students' performance changed with time under the teaching strategy of combining traditional teaching with problem-based learning (PBL). We can simulate data to reflect students' test scores at the beginning, middle and end of the course, as well as their performance in PBL activities.

The influence of course weeks on academic performance is shown in Figure 1.

By comparing the average scores of the two groups, we can see that the average scores of students in PBL combined teaching mode are slightly higher than those in traditional teaching mode in the whole semester. This may show that integrating problem-oriented learning into traditional teaching can effectively improve students' academic performance; judging from the standard deviation of grades, the fluctuation of students' grades in PBL combined teaching is slightly less than that in traditional teaching. This shows that PBL combined with teaching may be more effective in improving the stability of students' grades and students' performance is more balanced; the students' grades in the two teaching modes have improved with the increase of the number of weeks, which shows that with the deepening of the course, students' mastery is gradually enhanced in both traditional teaching and PBL teaching. However, the students in PBL combined teaching improved greatly in the later stage of the course, which may be related to the emphasis on practical problem solving and students' active learning in this teaching mode.

(2) Experiment 2: Complete PBL mode

The students' learning performance in the simulated PBL mode is shown in Figure 2.

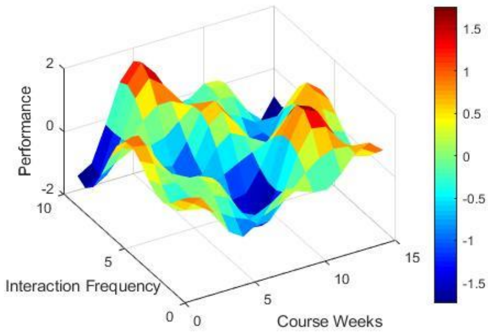

Figure 2: Students' learning performance in simulated PBL mode.

Students' learning performance shows a fluctuating trend with the increase of course weeks. This may indicate that under the PBL model, students have experienced challenges and growth at different stages in the learning process. At the beginning, students may be unstable because of adapting to the problem-oriented learning style. With the passage of time, through continuous practice and problem solving, students' performance has improved and stabilized.

(3) Experiment 3: SCL combined with technical tools

The test results of SCL combined with technical tools are shown in Figure 3.

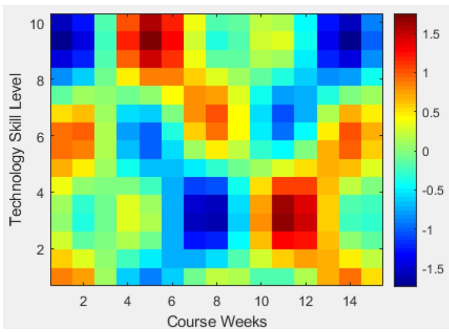

Figure 3: Test results of 3.SCL combined with technical tools

By observing the heat map, we can analyze the simulation data of the experiment of "SCL combined with technical tools" as follows:

The color change in the heat map shows that with the improvement of technical skills, the learning effect also shows an upward trend. This shows that in the student-centered learning environment, a good degree of technical mastery is very important to improve the learning effect; as can be seen from the heat map, with the increase of course weeks, the learning effect at different technical levels has improved, especially in the middle and late stages. This may be related to the gradual increase of students' proficiency in technical tools, and it also reflects the positive role of continuous learning and practice in improving skills; the dark areas in the heat map (indicating high learning effectiveness) are mainly concentrated in the students with high technical skills, especially in the second half of the course.

(4) Experiment 4: PBL mixed with SCL

Evaluation tools: comprehensive performance evaluation and self-evaluation report.

The results of learning effectiveness analysis of PBL and SCL mixed mode are shown in Table 1.

Table 1: Results of learning effectiveness analysis of PBL and SCL mixed mode

Number of weeks	Student group	Average participation rate	Average academic performance	Number of classroom interactions	Project completion rate	Student satisfaction score
one	A	75%	82	30	70%	88
one	B	80%	eighty-five	35	75%	90
2	A	78%	84	40	72%	eighty-nine
2	B	85%	88	45	78%	92
three	A	80%	86	50	75%	91
three	B	88%	90	55	80%	93
...	...	...	...	...	...	...
15	A	95%	95	70	95%	96
15	B	ninety-seven percent	98	75	ninety-seven percent	98

According to the data table provided, we can make the following analysis to evaluate the effect of the mixed teaching mode of PBL and SCL:

The data shows that with the progress of the course, the average participation of the two student groups (A and B) has gradually increased. This shows that students' interest and enthusiasm for participating in the course content increase with time. Especially in the later period, the significant increase in participation may be related to students' gradual adaptation to PBL and SCL teaching methods; judging from the average academic performance, the scores of the two groups of students also showed a steady upward trend. This may reflect that the mixed teaching model can effectively support students' academic growth, especially when they are more active in participation and interaction; the number of classroom interactions increases with the number of weeks, which may be because students are more accustomed to the interactive learning environment of PBL and SCL, or because teachers gradually increase the opportunities for classroom interaction. This increased interaction helps to enhance students' sense of participation and learning motivation; the improvement of the project completion reflects the enhancement of students' ability in practical operation, which shows that students have made progress in applying what they have learned to solve practical problems. This progress is consistent with the teaching goal of PBL, that is, to enhance the learning effect through practical activities; the score of students' satisfaction has gradually improved, which shows that students have a high degree of acceptance of curriculum design and teaching methods and feel a positive learning experience.

(5) Experiment 5: Case teaching mode

The results of student performance analysis of innovative project-driven mode are shown in Table 2.

Table 2: Analysis results of students' performance in innovative project-driven mode

Number of weeks	Student group	Technology application score	Innovation capability score	Team collaboration effectiveness	Project completion rate	Student satisfaction score
one	A	75	70	80	60%	eighty-five
one	B	80	75	eighty-five	65%	88
2	A	seventy-eight	seventy-two	82	62%	86
2	B	82	seventy-eight	88	67%	eighty-nine
three	A	80	74	84	65%	87
three	B	eighty-five	80	90	70%	90
...	...	...	...	...	...	...
15	A	95	90	95	95%	96
15	B	98	93	98	ninety-seven percent	98

By observing Table 2, we can draw the following analysis from several key indicators:

As can be seen from the data table, the students' technical application scores gradually increased from an average of 75 points in the first week to an average of 96.5 points in the 15th week (the average of two groups, 95 points in group A and 98 points in group B). This shows that with the deepening of the project, students' ability in technology application has been significantly improved; the innovation ability score also showed a similar growth trend, from the average of 72.5 points in the first week to the average of 91.5 points in the 15th week (90 points in Group A and 93 points in Group B). This reflects that the innovative project-driven model has effectively promoted the development of students' innovative thinking; the score of teamwork effect also showed a positive growth, from the average score of 82.5 in the first week to the average score of 96.5 in the 15th week (95 in Group A and 98 in Group B). This shows that students' teamwork and communication skills have been enhanced in continuous project practice; the project completion also showed a steady improvement, from the average of 62.5% in the first week to the average of 96% in the 15th week (95% in group A and 97% in group B). This shows that students can effectively apply the knowledge and skills they have learned to complete the project tasks; students' satisfaction with the course has always remained at a high level, from an average of 86.5 points in the first week to an average of 97 points in the 15th week (96 points in Group A and 98 points in Group B). This high degree of satisfaction may be directly related to students' sense of accomplishment in technology application, innovation ability and teamwork.

Through the above data analysis, we can see that the innovative project-driven model has shown remarkable positive effects in promoting students' technical application ability, innovative thinking, teamwork ability and overall project completion. In addition, students' high satisfaction with this teaching mode also shows the effectiveness and attractiveness of this teaching strategy. This teaching mode is worth popularizing and applying in a wider range of educational scenes, so as to cultivate more students with high innovation ability and good teamwork ability.

(6) Experiment 6: Innovative project-driven model

The performance of students in the innovative project-driven mode is shown in Figure 4.

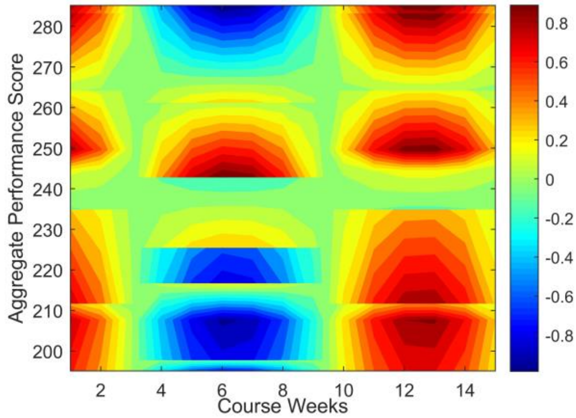

Figure 4: Students' Performance in Innovative Project-driven Mode

Contour maps provide an intuitive way to view data changes and trends. By analyzing this contour map based on simulated data, we can draw the following insights:

The figure shows that with the increase of course weeks, students' comprehensive performance index gradually improves. This trend shows that under the innovative project-driven mode, students' technical application ability, innovation ability and project completion degree have been significantly improved over time. This may be because with the deepening of the project, students have a deeper understanding of technology and innovative methods, and at the same time they have gained more experience in practice; dense areas of contour lines indicate rapid changes in performance index, while sparse areas indicate relatively stable performance. As can be seen from the figure, students' performance tends to be stable in the middle to late stage, which may be related to their adaptation to the teaching mode and project requirements; the change of color depth in the picture shows the peaks and valleys of students' performance. Dark areas may represent students' outstanding performance in certain stages or skills, while light areas may mean that students still have room for improvement in these areas; by observing the changing pattern of students' performance, educators can identify which teaching strategies are the most effective and the time or content that may need to be adjusted. For example, if the performance index has not improved significantly in a certain period of time, it may be necessary to adjust teaching methods or increase support.

This picture provides educators with a tool to evaluate and optimize the teaching mode, and helps them better understand the relationship between teaching effect and students' progress by intuitively showing the dynamic changes of students' performance. Through this analysis, we can further optimize the curriculum design and ensure that teaching activities can effectively promote the development of students' technical mastery, innovative thinking and project completion ability.

5. Conclusion

This study explores the innovative teaching mode of courses in private universities from the perspective of "double innovation education" through empirical analysis. Through the design, implementation and evaluation of six different teaching modes, this study mainly draws the following conclusions: The combination of problem-based learning (PBL) and student-centered learning (SCL) can significantly enhance students' interest in learning, participation and academic performance. In particular, the complete PBL model and the mixed model of PBL and SCL are particularly outstanding in improving students' innovative thinking and problem-solving ability. Although this study is fruitful, there is only one thing that needs to be improved and deepened in the future research: this study mainly focuses on the short-term teaching effect, and there is still a lack of systematic tracking and analysis of the long-term impact. Future research can design a long-term follow-up evaluation mechanism to evaluate the lasting effect of teaching mode more comprehensively. The current research samples are limited to specific private universities and student groups, and future research can be extended to different types of universities and more diverse student backgrounds to improve the universality and adaptability of the research.

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