Research on the Precise Teaching Model of Primary School Mathematics Empowered by Technology

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Abstract: In order to solve the problem of low teaching effect of traditional teaching mode, the research on precise teaching mode of primary school mathematics under technology empowerment is proposed. This study integrates the personalized recommendation module of collaborative filtering and the path optimization module of reinforcement learning. Firstly, the learning content is dynamically adjusted based on the students' learning history, behavior data and real-time feedback to ensure that students get the learning experience that best suits their individual needs. Secondly, the algorithm is applied in three subjects: mathematics, physics and English. Finally, the test scores and the number of interactions are verified by experiments. The experimental results show that the average test score of students has increased by 17.97%, among which the score of physics has improved the most significantly, with an improvement of 19.83%. This shows that the effect of personalized recommendation and learning path optimization is outstanding, which can help students better master complex knowledge points and significantly improve students' subject understanding and test performance. Conclusion: The algorithm provides effective technical support for personalized education and has broad application prospects.

Keywords: Big Data Analysis; Precision Teaching; Personalized Recommendation

1. Introduction

Personalized learning in primary school mathematics is an educational model in which educators comprehensively evaluate learners, discover and solve their learning problems, and customize different learning strategies and methods for each learner to improve their learning effectiveness [1]. There are personality differences among primary school students. It is the key to promote the in-depth implementation of quality education that teachers respect their individual differences and carry out personalized learning based on the characteristics, advantages, and interests of each student [2]. In practice, the personalized learning model can significantly improve students' learning effects and interests. The use of modern information technology can better understand the learning characteristics and needs of each student, formulate personalized learning plans, implement teaching in accordance with their aptitude, and cultivate students' autonomous learning ability and creativity [3].

In the era of big data, in order to ensure the standardized and orderly implementation of precision teaching activities in primary school mathematics, it is necessary to make full use of big data technology, comprehensively integrate and analyze students' learning behavior, learning results, learning status and other learning information, accurately judge students' growth and development potential and autonomous learning needs, and formulate effective teaching plans based on this, so as to ensure the effectiveness and accuracy of mathematics classroom teaching [4]. At the same time, in the process of carrying out precision mathematics teaching activities, teachers should use big data technology to capture students' dynamic learning situation according to the basic mathematical ability of students in the class, and give timely reminders and guidance, so as to mobilize students' enthusiasm and initiative to participate in classroom learning, and achieve the purpose of improving the quality and efficiency of primary school mathematics classroom teaching as much as possible [5].

The application value of big data technology in the precision teaching of primary school mathematics is becoming increasingly prominent. It can not only accurately analyze and identify the knowledge gaps of students in mathematics classroom learning, scientifically design precise teaching goals that match the learning situation, and comprehensively develop effective precision teaching plans and teaching questions under the guidance of the goals to ensure the overall quality and effectiveness of precision teaching of primary school mathematics; it can also accurately regulate the students' learning process, while ensuring that students can carry out in-depth learning of mathematical knowledge efficiently, further improve the accuracy and effectiveness of mathematics classroom teaching, and thus lay a solid foundation for cultivating students' comprehensive mathematical ability [6]. It can be seen that strengthening the analysis and research on the precision teaching strategy of primary school mathematics under the perspective of big data is of great practical significance.

2. Literature Review

Mathematics, as an important tool subject, runs through every student's learning career. The mathematics content of lower grades is relatively simple, and students can basically get full marks in mathematics. Therefore, students are also full of confidence in learning mathematics [7]. As the difficulty of mathematics courses gradually increases and the content of mathematics learning continues to increase, some students with weaker receptive abilities find it difficult to keep up with the course progress. At the same time, some teachers' teaching arrangements lack order and pertinence, and the differences in students' personal learning qualities make different students show different states in mathematics learning [8]. Over time, primary school mathematics learning results have gradually become differentiated, which is obviously not conducive to students' future development. In response to the phenomenon of differentiation in primary school mathematics results, teachers need to formulate strategies to solve the problem and help students improve their mathematics results.

In the 1960s, Guo, J., et al. proposed the concept of precision teaching. In order to solve the problem that the class teaching method was difficult to grasp the learning status of the whole class and solve the problem of students' individual needs, he borrowed Skinner's behaviorist learning viewpoint and applied programmed teaching to the tracking and diagnosis of students' learning situation [9]. The students' behavior was recorded by pencil drawing, and the data was used to manually analyze the students' learning behavior, providing support for teachers to achieve accurate evaluation of the teaching process, thereby helping teachers to make correct teaching decisions [10]. It can be seen that precision teaching is essentially an efficient teaching method that records, counts and analyzes the frequency of students' learning behavior to achieve a refined evaluation of classroom teaching effects [11]. In the 1970s and 1980s, Ou, S., et al. carried out a large-sample precision teaching practice project, which was used in student book reading, mathematics teaching, and special children's education, and achieved certain results [12]. However, due to the lack of advanced technical support, the measurement of students' academic performance relying on manual methods is too cumbersome, and precision teaching has gradually shown limitations in practical promotion. This has caused precision teaching to gradually be neglected in subsequent development and it is difficult to continue to be implemented in public schools abroad.

The development of information technology has provided strong technical support for precision teaching. Educational big data has made all kinds of educational information such as learning behavior, learning status, and learning results a digital existence that can be captured, quantified, and transmitted. After collection, classification, organization, and statistical analysis, learning data gradually accumulates to become the basis of educational big data. With the continuous improvement of big data analysis, it can promote the improvement of teaching quality and make teaching more intelligent, precise, and efficient. Based on big data analysis, this study designed and implemented a precision teaching algorithm, analyzed the practical effect of the algorithm, and explored the application prospects and challenges of the algorithm in educational practice.

3. Methods

3.1 Algorithm Overview

In the traditional teaching model, it is often difficult for teachers to fully understand the learning progress and needs of each student, and the teaching plan is usually oriented towards the whole [13]. Big data provides a new method for precision teaching. It can conduct in-depth analysis of each student's learning behavior, performance and other data, so that teachers can obtain more detailed feedback and formulate personalized teaching plans [14]. Precision teaching algorithm is the core tool for the application of big data in education. The algorithm uses data analysis, feature extraction and other methods to model students' learning behavior patterns and help teachers recommend personalized learning resources and paths for each student [15]. It can not only dynamically adjust according to students' learning history and performance, but also continuously optimize teaching strategies through learning feedback to achieve true "teaching students in accordance with their aptitude". The basic process of precision teaching method based on big data analysis is shown in Figure 1.

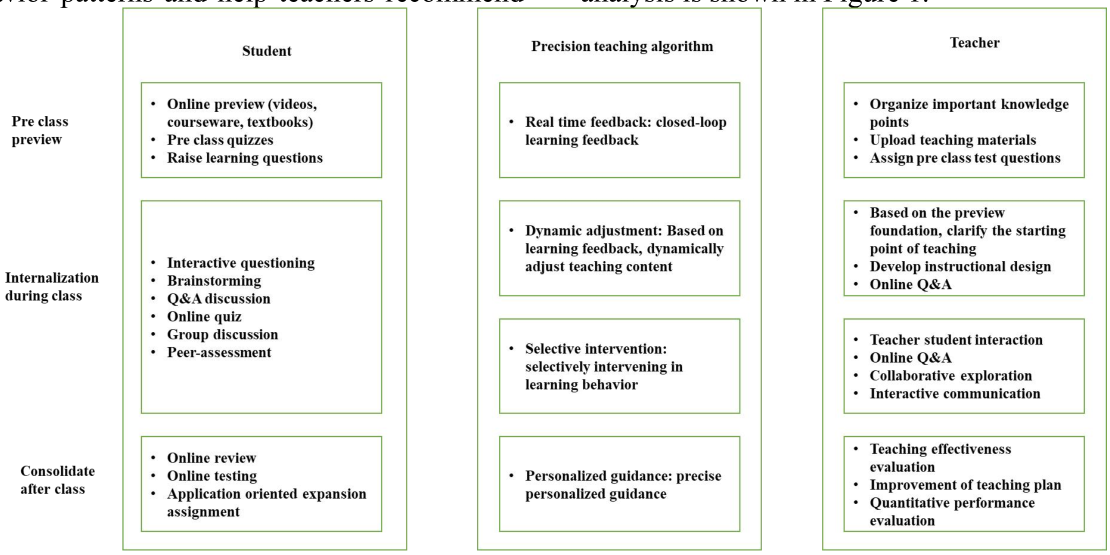

Figure 1. Basic Process of Precision Teaching Method based on Big Data Analysis

3.2 Precision Teaching Algorithm based on Big Data Analysis

3.2.1 Data Collection and Preprocessing

Data collection covers multiple aspects such as students' pre-class preparation, in-class interaction, and post-class consolidation. Before class, the system will collect students' online preparation information, such as study time, completion, study duration, and questions raised during the preparation process; during class, the system will collect classroom interaction data, including class participation, number of questions answered, group discussion records, and online test results to evaluate students' immediate performance; after class, the system will collect students' online review frequency, homework submission, and completion of consolidation exercises to ensure that students' learning process is fully tracked [16].

The sources of students' learning behavior data and teachers' feedback data are diverse and complex during the collection process, and may contain missing values, outliers, or inconsistent formats [17]. For missing data, mean filling or interpolation can be used to handle it. Assuming that the learning time T_i of student i is missing, the average value μ_T of all students' learning time can be used to fill it. The calculation formula is shown in formula (1):

$$T_i = \mu_T = \frac{1}{n}\sum_{i=1}^{n} T_i \quad (1)$$

In formula (1), n is the number of students. But sometimes outliers may affect the accuracy of the algorithm, and a more commonly used method is the Z score test. The calculation formula of the Z score is shown in formula (2):

$$Z = \frac{T_i - \mu_T}{\sigma_T} \quad (2)$$

In formula (2), μ_T is the mean of the learning time, and σ_T is the standard deviation. If the absolute value of a Z value is too large, the data is considered abnormal and can be removed or replaced by interpolation [18].

In the precision teaching system, the dimensions of data features may be different, and the data needs to be normalized. The calculation formula is shown in formula (3):

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (3)$$

In formula (3), X' is the processing result, X is the original data, X_{min} and X_{max} are the minimum and maximum values of the feature respectively [19].

3.2.2 Personalized Recommendation Algorithm

In order to enhance students' learning outcomes, the researchers selected a personalized recommendation algorithm based on collaborative filtering to analyze the learning behaviors and interest preferences of different students, predict resources that students may be interested in, and provide accurate recommendations.

In the precision teaching scenario, students' behavior data covers learning time, course completion, test scores, homework performance, etc. This type of data is processed by collaborative filtering algorithms to generate a recommendation list. This system adopts the user-based collaborative filtering method in collaborative filtering, analyzes the similarity of learning behaviors between students to recommend resources, and constructs a student-resource matrix R, where R_{ij} represents the score or learning performance of student i on learning resource j [20]. The score is calculated based on student completion, test scores or learning time. In order to find the student with the most similar learning behavior to the target student, the similarity between students needs to be calculated, which can be measured by cosine similarity. The formula for calculating the similarity of learning behaviors of two students A and B is shown in formula (4):

$$\mathrm{sim}(A,B)=\frac{\sum_{j=1}^{n} R_{Aj}\cdot R_{Bj}}{\sqrt{\sum_{j=1}^{n} R_{Aj}^{2}}\cdot\sqrt{\sum_{j=1}^{n} R_{Bj}^{2}}} \quad (4)$$

In formula (4), R_{Aj} and R_{Bj} represent the scores of students A and B on resource j, respectively. The higher the similarity value, the more similar the learning behaviors of the two students are.

After calculating the similarity, the system will recommend the target student the resources that the student with the highest similarity has already learned. The formula for calculating the recommendation score $P_{i,j}$ is shown in formula (5):

$$P_{i,j}=\frac{\sum_{k\in S}\mathrm{sim}(i,k)\cdot R_{k,j}}{\sum_{k\in S}\mathrm{sim}(i,k)} \quad (5)$$

In formula (5), S is the set of students similar to student i, and $R_{k,j}$ is the score of student k on resource j.

The algorithm also has the ability to dynamically adjust and update the recommendation list based on the student's real-time learning performance. Specifically, when a student performs well in a specific chapter, the system will automatically push more complex advanced learning content. For students who perform poorly, basic review materials will be recommended.

3.2.3 Learning Path Optimization Algorithm

Reinforcement learning regards the student's learning state as the "environment" of the system. The system selects "actions" based on the current environment, that is, recommends the next learning module or adjusts the learning content. This process can optimize the student's learning path and maximize learning benefits. The Q learning algorithm in reinforcement learning is widely used in path optimization to evaluate the quality of each combination of learning state and action and adjust the recommendation strategy. The Q learning algorithm update is shown in formula (6):

$$Q(s_t,a_t)=Q(s_t,a_t)+\alpha\left[r_t+\gamma\max_{a_{t+1}}Q(s_{t+1},a_{t+1})-Q(s_t,a_t)\right] \quad (6)$$

In formula (6), $Q(s_t, a_t)$ represents the quality of the student's execution of action a_t in the current state s_t; r_t is the immediate reward, which measures the effect of the current learning behavior; α is the learning rate, which indicates the rate of learning new knowledge; γ is the discount factor.

The optimization of learning paths also involves the design and adjustment of global paths. The goal of the system is to find a path that can maximize students' learning effects with the help of reinforcement learning algorithms. In this process, learning time and knowledge mastery are the two main optimization indicators. The system hopes to help students complete learning tasks more efficiently by minimizing learning time, while ensuring that students maximize their mastery of knowledge points.

3.3 Practical Application Analysis

This study selected an online education platform of a middle school, which covers multiple subjects and serves more than 500 students. In this platform, students learn and review knowledge points by completing online learning tasks, participating in tests and submitting homework.

In the data collection stage, the system comprehensively records the students' learning behaviors on the online education platform. The data collection cycle is one month, with the aim of collecting sufficient sample data to support the analysis of personalized recommendations and learning path optimization. In the algorithm implementation stage, the system adopts a personalized recommendation algorithm based on collaborative filtering and a learning path optimization algorithm based on reinforcement learning. By constructing a student-resource matrix and calculating the similarity between students, the system recommends high-quality resources that have been learned by other students with similar learning behaviors to each student. The reinforcement learning algorithm adjusts the learning path based on the students' real-time feedback and updates the instant rewards of each learning module to ensure that the recommended learning content always meets the needs of students. In the effect evaluation stage, the system analyzes the students' learning performance before and after implementation to evaluate the effectiveness of the algorithm. Throughout the process, the students participating in the practice complete their learning tasks on the online education platform every day, and the system automatically records the relevant data.

4. Results and Discussion

This study implemented personalized recommendation algorithms and learning path optimization algorithms in three subjects: mathematics, physics, and English. Table 1 shows the comparison of the average daily learning time before and after the application.

Table 1. Comparison of Average Daily Study Time

discipline	Before application(h)	After application(h)	Improvement (%)
math	2.08	1.63	21.63
physics	1.92	1.41	26.56
English	2.17	1.59	26.73

According to Table 1, the average daily study time of each subject has improved by 25.24%, with English being the most significant, with an improvement of 26.73%. This shows that with the help of personalized recommendations and learning path optimization, students' learning efficiency in all subjects has been significantly improved.

Table 2. Comparison of the Average Number of Tasks Completed by Students before and after the Application

discipline	Before application	After application (pcs)	Improvement (%)
math	4.28	6.96	62.62
physics	3.74	5.79	54.81
English	4.07	6.38	56.76

As shown in Table 2, the average number of tasks completed by students increased by 58.31%. Among all subjects, the increase in the number of tasks completed in mathematics was the most significant, with an improvement of 62.62%. This shows that students' learning efficiency in mathematics learning has improved significantly, showing a stronger enthusiasm for learning.

Table 3. Comparison of Students' Average Test Scores before and after the Application

discipline	Before application (minutes)	After application (minutes)	Improvement (%)
math	75.32	88.47	17.46
physics	70.26	84.19	19.83
English	78.49	91.67	16.79

As shown in Table 3, the average test score of students increased by 17.97%, among which the score of physics improved the most significantly, with an improvement of 19.83%. This shows that personalized recommendation and learning path optimization are effective, which can help students better master complex knowledge points and significantly improve students' subject understanding and test performance.

Table 4. Compares the Average Daily Number of Interactions before and after the Application

discipline	Before application (times)	After application (times)	Improvement (%)
math	2.12	3.43	61.79%
physics	1.98	3.07	55.05%
English	1.69	2.68	58.58%

As shown in Table 4, the average number of student interactions increased by 58.55%, among which the number of mathematical interactions increased most significantly, reaching 61.79%. This shows that personalized learning programs can help students to communicate more actively in learning, greatly enhancing students' interactive participation in the learning process.

5. Conclusion

This paper proposes a research on the precise teaching mode of primary school mathematics under the empowerment of technology. This study is committed to the application of big data technology, and designs and implements a precise teaching algorithm for primary school mathematics. The algorithm covers two core parts: personalized recommendation and learning path optimization. In practical applications, the recommendation algorithm based on collaborative filtering and the path optimization strategy of reinforcement learning are adopted, which significantly improves students' learning efficiency and academic performance. In the future, the precise teaching algorithm is expected to be further applied to more subjects, promote the in-depth development of personalized education, and provide strong support for the improvement of education quality.

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