Comprehensive Evaluation of Online Experimental Teaching Quality in Colleges and Universities Based on Support Vector Machine

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Abstract—Affected by the global COVID-19 epidemic, many universities in China have to carry out online experimental teaching. Online experimental teaching can fully realize retention of experimental teaching data, the maximum sharing of experimental teaching, and improve teachers' ability to complete experimental teaching by mobile means through good network storage devices. Scientific and systematic evaluation of online experimental teaching quality can promote continuous improvement of online teaching activities, give full play to teachers' teaching enthusiasm, improve comprehensive training quality of college students, and make online experimental teaching a new trend of experimental teaching reform. Based on existing literature, this study analyzes the factors affecting the quality of online experimental teaching, puts forward evaluation indicators of online experimental teaching quality, and uses support vector machine training evaluation system to establish evaluation model of online experimental teaching quality in colleges and universities. Experimental results show that evaluation indicator of online experimental teaching quality proposed is relatively perfect, and has good applicability and popularization. The method based on the support vector machine has improved evaluation effect of online experimental teaching quality in colleges and universities. Output evaluation results are highly consistent with actual evaluation results. Online experimental teaching quality evaluation results are very objective and comprehensive. Conclusions have important reference value for online experimental teaching behavior analysis, improvement of online experimental teaching quality evaluation indicators, reduction of online teaching quality evaluation errors, and improvement of online teaching quality evaluation effect.

Keywords—support vector machine, online experimental teaching, teaching quality, quality evaluation

1 Introduction

Application of emerging technologies, such as industrial Internet and artificial intelligence, has made trend of educational informatization reform more obvious. Higher education is the main field of educational informatization reform. To adapt to the development of China's new round of technological revolution, concept of "new engineering" was put forward in China in 2016. Higher engineering education is one of the main forces to promote the transformation of China's current economic structure, and to promote sustainable development of the economy and society. Higher engineering education talents are also greatly demanded by enterprises in the industrial sector. To further improve talent training of engineering colleges and universities, while teaching basic professional theories, engineering colleges and universities also need to combine more complex industrial scenes and more foreword application principle knowledge to accumulate knowledge of higher engineering professionals. However, since the end of 2019, many Chinese colleges and universities have had to carry out online teaching due to the impact of China's COVID-19. Therefore, making full use of the driving power of Internet development, building a new online experimental teaching innovation platform for universities to meet the needs of social development will add new vitality to engineering education.

The full outbreak of COVID-19 poses a serious challenge to China's higher education. All disciplines of the university have launched online teaching mode to ensure that education will not stop. Online education is conducted in form of live broadcast, recording and broadcasting. The closure of experimental environment under epidemic situation makes it impossible for students to conduct experimental research on the knowledge they have learned and truly grasp the essence of subject knowledge. However, the autonomy, dispersion and separation of time and space of online learning mode are not completely suitable for traditional experimental teaching mode. Due to various factors, practice of online education is a difficult point in organization and implementation of teaching. With the development of information technology, there are many attempts and practices in online experimental teaching. For example, it may build a virtual simulation experiment platform, build a real-time online experimental teaching system based on the Internet of Things technology, and introduce low-cost, portable experimental instruments and learning kits. These online experimental teaching modes have characteristics of simple operation, low cost and good teaching effect. In face of such cross-time and non-synchronous experimental needs, online experimental teaching method has been gradually adopted by more and more universities because of its characteristics of breaking through limitations of time and space. Research and analysis of online experimental platform can promote combination of basic knowledge and experimental teaching under epidemic situation, and enrich construction and improvement of online teaching system of various disciplines in universities. In the process of using the Internet to promote development of education, many colleges and universities in China have made full use of opportunities of the development of mobile Internet and developed online experimental platforms for higher education relying on mobile phones and other mobile terminals. In general higher education, good teaching quality of experimental teaching mainly comes from rich teaching experience of teachers and online experimental teaching platform with good operability.

2 Literature review

In process of using the Internet to accelerate high-quality development of higher education, countries represented by the United States, Germany and Japan have always been at the forefront of the world, and quality of higher education is very obvious. At present, all countries in the world are making full use of opportunity of the development of mobile Internet to develop online experimental teaching platform with mobile terminal and other mobile terminals as the main user end.

In terms of online experimental teaching quality evaluation methods, Yang [1] adopted questionnaire survey and literature analysis to establish a distance education teaching quality index system, including 16 specific observation point secondary indexes, and used the AHP method to calculate results of distance education teaching quality index system. Wang et al. [2] adopted evaluation model based on fuzzy system theory, proposed an improved public physical education teaching quality evaluation system, and constructed a complete public physical education teaching quality evaluation system, aiming at defects of existing evaluation index system of public physical education teaching quality. Su et al. [3] used the best-worst method (BWM) to determine the weight of each dimension and criterion of MOOC quality, and used VIKOR analysis method to rank platform quality of the selected 5 websites. Bangert [4] adopted an exploratory factor analysis method and believed that teacher-student interaction, active learning, time to complete tasks and cooperation among students were the core influencing factors of online learning. Rovai et al. [5] adopted comparative experiment method to analyze contents of anonymous students' answers to 202 students' open teaching questions. Results showed that online course communication media caused some students' inconsistency between their preferred learning environment and actual learning environment. Jiang et al. [6] adopted fuzzy comprehensive evaluation method to analyze teaching quality of public physical education. Shen et al. [7] adopted Delphi method and analytic hierarchy process to study established nursing simulation teaching quality evaluation index system.

As for evaluation indicators of online experimental teaching quality, Daumiller et al. [8] analyzed the attitude and burnout of 80 teachers in online teaching. Results showed that teachers' learning approach goals were positively correlated with a shift in seeing online teaching as a positive challenge and beneficial to their ability development. Zhao [9] analyzed problems affecting quality of online higher education, examined standards of online teaching quality, and proposed a methodic framework for measuring process and results of online teaching, providing a practical guide for universities to evaluate quality of online teaching. Yang et al. [10] analyzed indicator system affecting quality of online course education, and provided practical strategies for teachers to design and provide effective online teaching. Bigatel et al. [11] investigated relationship between teaching behaviors, attitudes and beliefs that reflected potential ability of online teaching success. Results showed that factor analysis produced 7 reliable factors, which provided teachers with the professional development of key abilities to ensure success of online teaching. McGorry [12] believed that teacher-student interaction, student learning and technical support in online teaching were the main factors affecting quality of distance education. Chua et al. [13] argued that there were still concerns about quality of online courses. Quality assurance (QA) had emerged as a prominent issue, describing some fairly unique quality assurance processes used by 21 universities around the world, identifying five aspects, namely content creation, courseware development, adjunct faculty recruitment, teaching and delivery, as key factors affecting quality of online course instruction. Gopal et al. [14] collected 544 respondents who were studying business management or hospitality management courses in

Indian universities for analysis using structural equation models. Results showed that teacher quality, course design, timely feedback and student expectations were critical to high performance of online courses. Lee [15] explored the factors influencing quality of online education support services for Korean and American students, and the results showed that perception of quality of online support services was an important predictor of online learning satisfaction. Espasa et al. [16] found that teaching and learning environments with the potential of high-level feedback dialogue could improve quality of language online learning. Wei et al. [17] analyzed 356 undergraduates enrolled in an asynchronous online course of cross-campus general education in Taiwan and showed that students' self-efficacy and learning motivation had a direct positive impact on their results in online discussion. Polikoff et al. [18] showed that good teaching standards, teacher accountability system and teacher quality reform was the key to improving teachers' teaching quality. Peltier et al. [19] tested structural model of the drivers of online education, and results showed that guidance of teachers in online teaching, course structure, and changes in the roles of teachers and students had a significant impact on importance of enhancing online learning experiences. Li [20] drew on survey results of students of online language courses in a university in northern China, and the results showed that personalized learning environment, peer learning environment, and new school-to-work model helped maintain high quality of online learning. Singh et al. [21] showed that interactivity and cost-effectiveness were the key factors affecting students' positive attitudes towards online learning in Indian Institutes of higher Education. Jung [22] showed that seven dimensions to evaluate quality of e-learning were teacher-student interaction, staff support, institutional quality assurance mechanism, institutional reputation, learner support, information and publicity, and learning tasks. Ke et al. [23] collected the data of students of 28 online courses, and results showed that evaluation of online experimental teaching gradually appeared along with gradual improvement of online teaching, requiring teachers to further improve quality and efficiency of experimental teaching. As can be seen from the existing research literature, online teaching mode has become one of the more mature teaching methods, more and more colleges and universities have adopted online teaching mode. At the same time, experimental teaching is a key measure to improve quality of talent training in higher education, and it has become an inevitable trend to complete experimental teaching through online means.

Scientific evaluation of online experimental teaching quality is an important aspect of improving teaching quality. Scientific evaluation results can help improve teachers' teaching quality, enrich students' learning content and ensure integrity of teaching process. Therefore, this study constructs an evaluation system of online experimental teaching quality in colleges and universities, designs an evaluation scale combined with five-level scoring standard, takes evaluation activities of online teaching quality in universities as an example, investigates progress of online teaching, fills in the scale, collects relevant data for simulation experiments, and trains system with the method of support vector machine (SVM), to achieve online experimental teaching quality comprehensive, objective evaluation.

3 Methodology

3.1 Model introduction

SVM is a relatively common data mining method at present, which is effective in dealing with regression problems and pattern recognition problems, etc., so it is widely used in comprehensive evaluation requirements. Optimal classification hyperplane conforming to classification standard is obtained, which can not only maintain classification accuracy, but also maximize blank range on both sides. For linear fractional data, SVM can obtain the best classification results. It sets (x_i, y_i), $i = 1, 2, \ldots, l$, $x \in \{\pm 1\}$, which represents the training sample set, and the number of samples is described as l. It uses $(w \cdot x) + b$ to describe hyperplane. Classification shall satisfy the constraint conditions as shown in formula (1), to ensure that it can accurately classify all samples, and that classification interval exists.

$$y_i[(w \cdot x) + b] \geq 1 \tag{1}$$

In formula (1), w represents vector perpendicular to the hyperplane, and b represents hyperplane bias. $\frac{1}{2}\|w\|^2$ represents classification interval and converts optimal hyperplane establishment problem. Under constraints, solution is shown in formula (2).

$$\min \Phi(w) = \frac{1}{2}\|w\|^2 = \frac{1}{2}(w \cdot w) \tag{2}$$

Among them, Φ represents non-negative relaxation factor. Lagrange function shown in formula (3) is used to solve the optimization problem under constraints.

$$L(w,b,a) = \frac{1}{2}\|w\|^2 - \sum_{i=1}^{l} \alpha_i (y_i((w \cdot x_i) + b) - 1) \tag{3}$$

In formula (3), α_i represents Lagrange multiplier, and $\alpha_i > 0$. Saddle point of Lagrange function has a decisive effect on solution of constrained optimization problem. At the saddle point position, partial derivative of w and b parameters is zero, which is the condition that solution of this problem meets. The problem is transformed into a dual problem, as shown in formula (4).

$$\begin{aligned} &\max Q(\alpha) = \sum_{i=1}^{l} \alpha_i - \frac{1}{2} \sum_{i=1}^{l} \sum_{j=1}^{l} \alpha_i \alpha_j y_i y_j (x_i \cdot y_i) \\ &s.t. \sum_{j=1}^{l} \alpha_j y_j = 0,\ j = 1,2,\ldots,l,\ \alpha_j \geq 0 \end{aligned} \tag{4}$$

In formula (4), α_i and α_j represents Lagrange multiplier of different samples. The optimal solution is shown in formula (5).

$$\alpha^* = (\alpha_1^*, \alpha_2^*, \ldots, \alpha_l^*)^T \tag{5}$$

b^* represents the optimal bias, and w^* represents the optimal weight vector. Calculation formula is shown in formula (6) and formula (7).

$$b^* = y_i - \sum_{j=1}^{l} y_i \alpha_i^* (x_j \cdot x_i) \tag{6}$$

$$w^* = \sum_{j=1}^{l} \alpha_j^* y_j x_j \tag{7}$$

In addition, $j \in \{j \mid \alpha_j^* > 0\}$. $(w^* \cdot x) + b^*$ represents the optimal separating hyperplane. The optimal classification function expression is shown in formula (8).

$$f(x) = \operatorname{sgn}\{(w^* \cdot x) + b^*\} = \operatorname{sgn}\left\{\left(\sum_{j=1}^{l} \alpha_j^* y_j (x_j \cdot x_i)\right) + b^*\right\},\ x \in R^n \tag{8}$$

Input vector is mapped to a high-dimensional eigenvector space in which the optimal classification surface can be created. This process can be applied to the classification of linear non-fractional data. R^n is used to represent input space and H is used to represent feature space. Input vector x is mapped from R^n to H. Transformation process is shown in formula (9).

$$x \to \Phi(x) = (\Phi_1(x), \Phi_2(x), \ldots, \Phi_l(x))^T \tag{9}$$

$\Phi(x)$ represents characteristic vector. $\Phi(x)$ replaces with x, and the optimal classification function expression is shown in formula (10).

$$f(x) = \operatorname{sgn}\{(w \cdot \Phi(x)) + b\} = \operatorname{sgn}\left\{\left(\sum_{j=1}^{l} \alpha_j y_j \Phi(x)\right) + b\right\} \tag{10}$$

When the data is linear and non-separable, SVM usually uses penalty factors and relaxation variables to reduce probability of sample misclassification and to maximize the classification interval, but does not consider the cost of misclassification. Therefore, cost-sensitive learning theory is used to improve SVM. It sets $(x_i, y_i, \mathrm{cos}t_i)$, which represents sample collection, and $x_i \in R^n$, $y_i \in \{-1, 1\}$, $\mathrm{cos}t_i \geq 0$. $\mathrm{cos}t_i$ represents fault points and the cost of sample i. The constrained optimization problem is transformed into a problem-solving formula (11).

$$\begin{aligned} &\min \Phi(w,\xi) = \frac{1}{2}\|w\|^2 + C\left(\sum_{i=1}^{l} \cos t_i \xi_i\right) \\ &s.t.\, y_i(w \cdot x + b) + \xi_i \geq 1,\ \xi_i \geq 0 \end{aligned} \tag{11}$$

In formula (11), C represents penalty factor, ξ_i represents slack variable. Therefore, the error cost can be introduced into objective function and a cost-sensitive SVM can be obtained by solving above equation. The dual Lagrange expression of improved SVM is shown in formula (12).

$$\begin{aligned} &\max Q(\alpha) = \sum_{i=1}^{l} \alpha_i - \frac{1}{2} \sum_{i,j=1}^{l} \alpha_i \alpha_j y_i y_j k(x_i \cdot x_j) \\ &s.t. \sum_{j=1}^{l} \alpha_j y_j = 0,\ 0 \le \alpha_j \le \cos t_i C \end{aligned} \tag{12}$$

$k(x_i \cdot x_j)$ represents kernel function.

3.2 Evaluation indicators of online experimental teaching quality

Based on existing evaluation theories and principles, combined with actual situation of engineering education in colleges and universities, corresponding teaching quality evaluation indicators are designed in this study. Evaluation of online experimental teaching quality is completed by multiple subjects, including students, teachers, experts and leaders. Based on multiple evaluation objects, and combination of other evaluation and self-evaluation, it embodies organic combination of teaching and learning. All factors and processes affecting quality of teaching are considered, including design, preparation, implementation and management of teaching. Design of indicator system considers characteristics of the major comprehensively and covers all aspects of teaching process. Teaching quality evaluation is a process of judging value of teachers' teaching process and teaching effect, and it is an activity to guide teachers to improve teaching work and teaching quality. Therefore, on the basis of the higher education quality evaluation program of the Ministry of Education of China and characteristics of online experimental teaching, this study constructs an online experimental teaching quality evaluation indicator system of colleges and universities, which consists of 16 specific observation points. Importance of each indicator is different, and each indicator contains several correlations. Evaluation indicator of online experimental teaching quality in colleges and universities can get classification of teaching quality by scoring each indicator to promote improvement. Using improved SVM to train the system can not only get objective evaluation results but also greatly improve evaluation efficiency.

Table 1. Evaluation index system of online experimental teaching quality in colleges and universities

Evaluation Objective	Primary Indicator	Secondary Indicator	Secondary Indicator Number
Evaluation indicator system of online experimental teaching quality	Hardware equipment for online experimental teaching	Network stuck in the online experiment	X_1
		Good level of online experimental equipment	X_2
	Teacher Literacy in online experimental teaching	Teacher's level of Mandarin in online teaching	X_3
		Teachers' dress for online lectures	X_4
	Teaching content of online experiment	Teaching ideas are clear and close to the syllabus	X_5
		Teaching focus is prominent and the difficult points are analyzed thoroughly	X_6
		Teaching objective is scientific and reasonable	X_7
		Use class time effectively	X_8
	Teaching methods for online experiments	Using modern teaching methods	X_9
		Teaching strategy and process are reasonable	X_{10}
		Technical terms are expressed accurately	X_{11}
	Ability to teach online experiments	Stimulate students' interest in learning	X_{12}
		Teaching task is completed satisfactorily	X_{13}
		Interaction degree between students and teachers online	X_{14}
	After-school task for an online experiment	Rationality of after-school tasks	X_{15}
		How seriously the teacher corrects the homework	X_{16}

3.3 Data source

Due to the COVID-19 pandemic in China, many universities have resorted to online teaching. In this study, eight teachers from some universities in Haikou, Hainan Province, China, conduct online experimental teaching process of "College Computer Basics" in the spring semester of the 2021–2022 academic years on online experimental teaching process to evaluate effect. A questionnaire (Likert scale of 5-point) is used to conduct a questionnaire survey on 385 junior students. Evaluation indicators in Table 1 are set as questionnaire options, and students' rate teaching quality of online experiment of "College Computer Basics" with scores of 1, 2, 3, 4 and 5. At the same time, evaluation grade of the online experimental teaching effect is set into four categories including excellent, good, pass and fail by school supervisor and the teacher, and qualitative evaluation results are converted into numbers, with 5 representing excellent, 4 representing good, 3 representing pass and 2 representing fail. The collected data is shown in Table 2.

Table 2. Table of collected data

Serial Number	X_1	X_2	X_3	…	X_{14}	X_{15}	X_{16}	Y
1	2	2	2	…	2	2	3	3
2	1	1	1	…	2	2	2	2
3	4	2	3	…	2	2	1	3
...	...	...	...	...	...	...	...	...
385	4	5	4	…	5	4	5	4

4 Experimental analysis

4.1 Descriptive statistical analysis

Table 3. Basic information summary of SVM classification

Name	Option	Frequency	Percentage
Effect of online experiment teaching	Fail	2	0.52%
	Pass	23	5.97%
	Good	131	34.03%
	Excellent	229	59.48%
	Total	385	100.00%
Summary	Effective	385	100.00%
	Deletion	0	0.00%
	Total	385	100.00%

In this study, 16 secondary indicators of online experimental teaching quality evaluation indicator system of colleges and universities are taken as independent variables, and evaluation level of online experimental teaching effect of the teacher by school supervisor and the teacher is taken as dependent variable to conduct SVM modeling. As can be seen from Table 3, a total of 385 samples are analyzed.

4.2 Training set and test set analysis

Table 4. Model summary table

Name	Parameter Name	Parameter Value
Model parameter setting	Data preprocessing	None
	Training set ratio	0.8
	Penalty coefficient of error term	1
	Kernel	rbf
	Kernel coefficient value	0.01
	Multi-classification decision function	ovr
	Model convergence parameter	0.001
	Maximum number of iterations	2000
Model evaluation effect	Accuracy rate	93.51%
	Accuracy rate (comprehensive)	94.03%
	Recall rate (comprehensive)	93.51%
	f1-score	0.93

It can be seen that indicator system of online experimental teaching quality proposed in this study reflects teaching process of teachers to some extent. Through evaluation and scoring of the indicator, the evaluator's evaluation of teachers' teaching can be obtained. According to the indicator data, the SVM classifier of the system can be called to automatically classify teaching quality. In this way, it can find out what kind of teaching quality the teacher belongs to and obtain results conveniently, quickly and objectively, to interact with teaching activities of teachers and promote improvement of teaching quality. SVM evaluation can eliminate constraints of manpower, region, material resources and time, improve efficiency of evaluation, improve interaction between teaching and evaluation, and help to improve teaching quality activities.

Table 5. Evaluation results of training set model

Item	Accuracy Rate	Recall Rate	f1-Score	Sample Number
Fail	1	1	1	2
Pass	1	1	1	15
Good	1	1	1	106
Excellent	1	1	1	185
Accuracy rate	–	–	1	308
Average value	1	1	1	308
Average value (comprehensive)	1	1	1	308

Table 6. Evaluation results of test set model

Item	Accuracy Rate	Recall Rate	f1-Score	Sample Number
Fail	0	0	0	0
Pass	1	0.75	0.86	8
Good	0.86	0.96	0.91	25
Excellent	0.98	0.95	0.97	44
Accuracy rate	–	–	0.94	77
Average value	0.94	0.89	0.91	77
Average value (comprehensive)	0.94	0.94	0.93	77

As can be seen from Tables 3 and 4, accuracy rate represents proportion of samples with correct prediction results in total samples. The accuracy of training set in this study is 1.00, and that of test set is 0.94, indicating that indicator system established is very good and evaluation results are in line with actual situation. In addition, value of f1-score indicates that online experimental teaching quality evaluation model proposed has a very good improvement effect. Proportion of training set is set to 0.8, and SVM modeling is carried out. Accuracy rate of final model on test set is 93.51%, accuracy rate (comprehensive) is 94.03%, recall rate (comprehensive) is 93.51%, and f1-score (comprehensive) is 0.93. The model effect is better. Therefore, it can be seen that using classification method of SVM to establish effect of online experiment teaching can reduce human intervention, reflect more objective actual situation of the data itself, and can well reflect objective conclusions.

Compared with other classical online experimental teaching quality assessment models, SVM method can reflect characteristics of more accurate, faster and more reliable in online experimental teaching quality assessment, mainly because the model proposed effectively integrates advantages of SVM to establish a better evaluation indicator system of online teaching quality. Therefore, through adoption of SVM, evaluation results of online experimental teaching quality can be more consistent with expected objectives and actual situation, with less deviation, and results are very good, which verifies effectiveness of the model.

5 Discussion

Improving quality of online experimental teaching is the focus of teaching authorities of higher education and an important part of evaluating teachers' teaching ability. Therefore, scientific evaluation of online experimental teaching quality can help teachers improve teaching methods and content quality. In practical application of teachers' teaching, quality of online experimental teaching involves a variety of evaluation indicators, which is a complicated evaluation problem. There are both quantitative and qualitative types of evaluation indicators, and there is mutual influence and interaction between indicators, which makes it more difficult to evaluate quality of online experimental teaching. In terms of online teaching quality synthesis, there are mainly fuzzy theory methods, and teaching quality evaluation results can be obtained according to fuzzy comprehensive evaluation [24–25]. The analytic hierarchy process is adopted to select evaluation indicators of network teaching quality, and indicators are quantitatively analyzed to establish quality evaluation model of network teaching quality evaluation system [26]. Alternatively, online teaching quality assessment model based on the Markov chain is adopted to conduct comprehensive assessment of online teaching quality combined with students' test scores [27–28]. At present, most of the literature on online experimental teaching quality evaluation adopts linear modeling method, which does not show that online teaching is a nonlinear process. Using linear evaluation method to evaluate quality of online teaching will have certain limitations. Nonlinear theory is applied more widely, and SVM can improve reliability of evaluation conclusions under condition of small sample data. In this study, online experimental teaching quality data of 8 universities in Hainan Province is used to verify the model. Practical application of this method can provide reference value for improving quality of online experimental teaching in universities.

6 Conclusions

The outbreak of global COVID-19 has made online teaching a trend, and experimental teaching, as an important teaching content to improve effectiveness of higher engineering education, has to adopt online teaching mode. Online experimental teaching puts forward higher requirements for intellectualization, convenience and interactivity of online education. Online experimental teaching can ensure integrity of online teaching content and sustainability of teaching process by meeting individual learning needs of learners. Traditional online teaching quality evaluation method only focuses on evaluation results, which is easy to ignore complex process of online teaching and to lead to high error of evaluation results. Online experimental teaching quality evaluation itself is a multi-class classification problem, and final choice of SVM method can improve accuracy and reliability of online teaching quality evaluation results. The following conclusions were obtained from this study: (1) According to the principle of teaching quality evaluation indicator, a more scientific and reasonable evaluation indicator system of online experimental teaching quality is constructed, and there is a nonlinear relationship between the indicators. (2) SVM algorithm is applied to online experimental teaching quality evaluation. Online experimental teaching quality evaluation model has high accuracy and efficiency for classification of teachers' teaching quality, and the model is feasible. It is suggested that further research should focus on improving evaluation indicator system of teaching quality in colleges and universities, improving prediction accuracy and training efficiency of teaching quality evaluation in colleges and universities.

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