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Research on evaluation of hybrid teaching reform based on hidden Markov

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Abstract: In order to improve the accuracy of the mixed teaching reform evaluation results, a hybrid teaching reform evaluation method based on hidden Markov is proposed. The information is collected from the PTA aided teaching platform, and the data of the mixed teaching reform is fused and preprocessed using support vector machine. Based on the principles of measurability and feasibility, the evaluation index system of mixed teaching reform is constructed. The hidden Markov theory is used to evaluate the effect of the mixed teaching reform. The experimental results show that the Cronbach coefficient α of the reliability and validity of the evaluation indexes selected in this paper is higher than 0.8, and the evaluation accuracy of the teaching reform evaluation method is as high as 97.6%, which shows that the research effect is remarkable.

Keywords: hidden Markov; hybrid teaching; reform evaluation; cross entropy; evaluation grade; index system.

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Hui-sheng Zhu obtained his PhD in Fudan University in 2011. He has presided over many national and Jiangsu Natural Science Foundation projects, the Ministry of education cloud number Integration Science and education

innovation project, the Ministry of education industry university cooperation collaborative education project, and published more than 40 papers in the international academic conferences ICDM and IJCNN recommended by the Chinese computer society, and the authoritative journals *Journal of Software*, *Journal of Computer Science*, and *Computer Research and Development*, Two invention patents were authorised.

1 Introduction

The advent of the Internet provides opportunities and means for the transformation of all walks of life, especially in the field of education, which can be described as a change that subverts the traditional teaching mode (Shi et al., 2021; Chen and Huang, 2021). The application of the Internet platform not only makes teachers away from the blackboard, but also enables students to take classes under no restrictions from regions or even locations. Teachers can impart knowledge to students in the form of online video lectures, check students' homework and hold examinations online, thus a new hybrid teaching mode arises at the historic moment. The hybrid teaching mode is an organic combination of online and offline teaching to improve students' learning effect. Its application can give full play to the guiding role of teachers and drive students' initiative and creativity in learning knowledge (Wang and Sha, 2021). However, since the application of the hybrid teaching mode, many scholars have evaluated its teaching reform, but the evaluation results have some problems in different degrees. Zhang (2022) puts forward the design and practice of online teaching evaluation based on OBE perspective. From the perspective of OBE, curriculum design and instructional design are oriented to the final result of learning output, and pay more attention to the mutual support among the setting of professional training objectives, selection of teaching contents, design of teaching methods and evaluation of teaching quality. The evaluation of learning output belongs to the whole process evaluation, which focuses on the process evaluation, involves the final evaluation, and pays attention to the effect of the final evaluation, thus forming a variety of online learning evaluation methods. These are all reflected in the evaluation process. However, the evaluation index of teaching reform selected by this method in the application process is too few, which leads to its poor effect in evaluating hybrid teaching reform. Xu (2022) puts forward the research on the construction of the evaluation index system for online teaching learning effect. A chain-type evaluation method in which teachers, students and supervisors are the main bodies and the diversified evaluation subjects run through the whole process of online teaching is formed, which is to provide reference and basis for further constructing the evaluation system for online teaching learning effect during the suspension of classes and non-stop study, so as to achieve the purpose of improving the learning effect of online teaching. However, the evaluation accuracy of this method is low in teaching reform evaluation. In order to improve the evaluation accuracy, the research of hybrid teaching reform evaluation based on hidden Markov is proposed in this paper. Hidden Markov Model (HMM) is a kind of statistical model, which can describe Markov processes with unknown parameters (Zhu and Zheng, 2020). HMM can present a dynamic Bayesian

network structure, and the target state output by HMM is invisible to the observer (Leopold et al., 2019). By marking the probability of the target state, the effect of each state in the data can be evaluated. Faced with the shortcomings of the evaluation methods of hybrid teaching model reform, the evaluation methods of hybrid teaching reform based on HMM is studied, and the effect of the current hybrid teaching reform is more fully presented. The specific research procedure of this paper is as follows:

- 1 The mixed teaching mode is divided into online teaching and offline teaching. Collect online teaching information from PTA assisted teaching platform, and input the record data of students' examination scores, attendance rate and classroom interaction times in offline teaching into statistics. Because the data type and statistical time of online teaching mode reform and offline teaching mode reform are different, support vector machine is used for fusion preprocessing of all data.
- 2 According to the prominent key indicators, as well as the measurable and feasible principles of the indicators, an evaluation index system for hybrid teaching reform is built, on which the current status of hybrid teaching reform is presented more comprehensively.
- 3 According to the evaluation index system, the fused data of hybrid teaching reform are input into the HMM, innovatively introducing the initial distribution probability description of the hidden Markov model for random variables, and the evaluation probability of hybrid teaching reform is output through model iterations. According to the corresponding relationship between the evaluation probability and the evaluation grade, the current evaluation result of hybrid teaching reform is obtained.

2 Evaluation method of hybrid teaching reform

2.1 Information sampling and fusion pre-processing

The hybrid teaching mode is divided into online teaching and offline teaching. At present, online teaching is given by PTA-assisted teaching platform (Chen, 2021; Ding et al., 2021; Lin et al., 2019), so the online teaching reform data of the hybrid teaching mode can be downloaded and exported from the PTA-assisted teaching platform. The data of offline hybrid teaching reform are students' test scores, attendance rate and interaction times in class, which are obtained by recording (Li and Perez, 2020). The total data are imported into the computer and calculated by statistical software. Because the data types and statistical time of online teaching mode reform and offline teaching mode reform are not uniform, there are classified variables and non-classified variables, ordered variables and non-ordered variables, and the data need to be fused and pre-processed (Wang and Xu, 2021). In this paper, SVM is used to fuse the data of hybrid teaching reform, and the detailed process is as follows:

x_{ip} is used to present the reform data of group l from m hybrid teaching reform data sources in a certain period of time. Then $x_i \in R^m$ is used to represent the data from m hybrid teaching reform data sources in each group. x_i is used to construct the SVM training set, and the set is represented by $y Z = (z_1, z_2, \dots, z_l)$. The true value of the

hybrid teaching mode reform data is represented by y , and $y \in R^l$. Set the data similarity threshold as. The specific determination process of threshold y is to compare each similarity with each candidate similarity threshold in the preset candidate threshold set to obtain the corresponding comparison results; Calculate the evaluation index of each candidate similarity threshold according to the comparison results; The target similarity threshold is defined as the candidate similarity threshold when the evaluation index reaches the index threshold. According to “3 σ ” the rule takes the size of y as the data length division unit, and determines y based on the similarity probability distribution of the initial collected data. Then the SVM outputs the fused hybrid teaching mode reform data as $Y = y$. The expression formula for fusion of hybrid teaching mode reform data by SVM is as follows:

$$\min_{z^{(i)} \in R^{3l}} \frac{\sum_{i=1}^l \sum_{j=1}^l (z_i^* - z_i)(z_j^* - z_j)K(x_i, x_j)}{2} + \varepsilon \sum_{i=1}^l (z_i^* + z_i) - y_i(z_i^* - z_i) \quad (1)$$

where ε is the generalisation parameter; $K(x_i, x_j)$ is the Gaussian kernel function; z_i and z_j are the reform data of hybrid teaching mode; y represents the data support function; i and j are the data sources of hybrid teaching mode reform.

The constraint conditions of Formula (1) are set, and the formula is expressed as follow:

$$\begin{cases} \sum_{j=1}^l (z_i - z_i^*) = 0 \\ 0 \leq z_i \\ z_i^* \leq \frac{\varphi}{l} \end{cases} \quad (2)$$

where φ represents the interface value on the hyperplane of the SVM, and l represents support vector. According to the constraint conditions of Formula (2), after solving Formula (1), the optimal solution set of data fusion of current hybrid teaching reform can be obtained, which is represented by $\bar{z} = (\bar{z}_1, \bar{z}_1^*, \dots, \bar{z}_l, \bar{z}_l^*)^T$.

The decision function of SVM output is established, and its expression formula is as follows:

$$f(x) = \sum_{i=1}^l (\bar{z}_i^* - \bar{z}_i) * \sum_{j=1}^l K(x_i \cdot x_j) + \bar{b} \quad (3)$$

$$\bar{b} = y_j - \sum_{i=1}^l (\bar{z}_i^* - \bar{z}_i) * \sum_{j=1}^l (x_i \cdot x_j) + \varepsilon \quad (4)$$

where $\bar{b}$ represents the offset value, which is within $(0, \frac{\varphi}{l})$. Formula (3) is used to judge the optimal solution set of the current hybrid teaching reform data fusion, and to judge whether the solution set satisfies the maximum hyperplane interval of SVM. If so, it is

judged that the optimal solution set is the final result of hybrid teaching reform data fusion, otherwise, the current optimal solution set is recalculated.

So far, the data fusion process of hybrid teaching reform from different sources has been completed, which provides data basis for the subsequent evaluation of hybrid teaching reform effect.

2.2 Construction of evaluation index system for the hybrid teaching reform

Based on the details of online and offline teaching activities in the hybrid teaching mode (Wu et al., 2021), and the prominent key indicators with the principle of measurability and feasibility, the evaluation index system for hybrid teaching reform is constructed, as shown in Table 1.

Table 1 Evaluation index system of mixed teaching reform

<i>Level I indicator</i>	<i>Secondary indicators</i>	<i>Indicator evaluation probability</i>	<i>Evaluation subject</i>
Moral cultivation	Integrity	Cheating at noon in the teaching process	Teacher
		No plagiarism in operation	Teacher
		Probability of completing the task on time	Teacher
	Sense of discipline	Abide by the learning agreement	Teacher/student
		Absenteeism rate	Teacher/student
		Observe the discipline of class and examination room	Teacher/student
Training of learning ability	Learning attitude	Follow the learning rules	Student
		Class attendance	Teacher/student
		Online learning duration	Teacher/student
	Learning ability	Number of login to teaching platform	Teacher/student
		Discussion participation	Teacher/student
		Classroom enthusiasm	Teacher/student
		Autonomous Learning Ability	Student
	Innovation ability	Team collaboration contribution rate	Student
		Reflection and improvement ability	Teacher/student
		Clarity of operation ideas	Student
		Skill proficiency	Student
		Innovative thinking ability	Student

Table 1 Evaluation index system of mixed teaching reform (continued)

<i>Level I indicator</i>	<i>Secondary indicators</i>	<i>Indicator evaluation probability</i>	<i>Evaluation subject</i>
Training of learning ability	Communication skills	Number of questions in the course	Teacher/student
		Contribution rate of group discussion	Student
Professional quality	Professional dedication and sense of responsibility	Completion degree of implementation plan objectives	Student
		Team collaboration contribution rate	Student
	Social adaptability	Adaptability to new learning environment	Teacher/student
		New technology acceptance	Teacher/student
Professional skills	Mastery of professional knowledge	Completion degree of professional work	Student
		Online and offline test results	Student

Then the evaluation index system for hybrid teaching reform has been built, which is the basis of evaluating the effect of hybrid teaching reform, and its quantitative measurement standard of hybrid teaching reform effect “The probability of evaluation”. It can be used to present the current effect and development status of hybrid teaching reform (Wang et al., 2021; Zhang, 2021). However, a single measurement index cannot fully present the effect of hybrid teaching reform, and it is easy to be affected by people. So it is necessary to select various first-level indicators and second-level indicators to build an evaluation index system for hybrid teaching reform. According to this index system, the status of hybrid teaching reform can be more comprehensively presented.

2.3 Evaluation method of hybrid teaching reform based on HMM

The hidden Markov model is able to calculate the probabilities of a system with multiple dimensional states. The evaluation index system of mixed teaching reform is multidimensional, so the hidden Markov model is used to solve the evaluation. Taking the data of hybrid teaching reform as input, the HMM is used to evaluate the effect of hybrid teaching reform according to the evaluation index system for blended teaching reform. The detailed process is as follows:

The hidden Markov evaluation model is composed of several Markov chains, and the expression formula of Markov chains is as follows:

$$P = (E_t = e_t | E_{t-1} = e_{t-1}, E_{t-2} = e_{t-2}, \dots, E_{t-n} = e_{t-n}) \quad (5)$$

where E is a random variable; t is the time point, $t \in n$; q_t is the state quantity of the evaluation effect of the hybrid teaching reform.

Assuming that the random variable E satisfies the n -order Markov process, when the order is equal to 1, the Formula (5) becomes the first order Markov chain, and its expression formula is as follows:

$$P_{i,j}(E_t, e_{t-k}) = P(E_t = e_j | E_{t-k} = e_i) \quad (6)$$

where k is a time constant. When the constant value is equal to 1, the one-step transition probability of formula (6) is expressed as o_{ij} , and the transition probability matrix is expressed as follows:

$$O = \begin{pmatrix} o_{11} & \cdots & o_{1N} \\ \vdots & \ddots & \vdots \\ o_{N1} & \cdots & o_{NN} \end{pmatrix} \quad (7)$$

where O represents the transition probability matrix, $0 \leq o_{ij} \leq 1$ and $\sum_{j=1}^N o_{ij} = 1$. In this formula, the one-step transition probability o_{ij} also describes the adjustment probability.

There is one-sidedness when using transition probability to describe Markov chain. In order to avoid this situation, the initial distribution probability of random variable E is introduced into it. When the time is 1, the initial distribution probability vector set of random variable E is $p = (\pi_1, \dots, \pi_N)$, where π_i represents the initial distribution probability vector of random variable, and its expression formula is as follows:

$$\pi_i = P(E_i = e_i) \quad (8)$$

where $0 \leq \pi_i \leq 1$ and $\sum_{i=1}^N \pi_i = 1$.

Based on the results of the above formulas, the expression formula of hidden Markov evaluation model is as follows:

$$\zeta = (N, M, \pi, O, U) \quad (9)$$

where N and M represent the total number of implicit states and the total number of observed states of the HMM, respectively; O represents the state transition probability matrix; π represents the initial distribution probability of random variable; B is the emission probability from hidden state to observable state, and its expression formula is as follows:

$$U = (u_{jm})_{N \times M} \quad (10)$$

where u_{jm} represents the probability value of transition from state j to state m .

Formulas (7), (8)–(10) are substituted into formula (9), and this formula is used to output the probability value of hybrid teaching reform. The probability value is divided into five evaluation grades, and the corresponding relationship between the probability value and the evaluation grade is shown in Table 2.

The evaluation probability of hybrid teaching reform is output through model iteration. According to the corresponding relationship between the evaluation probability and the evaluation grade, the current evaluation result of hybrid teaching reform is obtained.

Table 2 Correspondence between hidden Markov evaluation probability value and evaluation grade

<i>Evaluation grade</i>	<i>Probability value</i>
Very bad	0–0.19
Bad	0.2–0.29
Inferior	0.30–0.39
Commonly	0.4–0.59
Preferably	0.6–0.79
Good	0.8–0.89
Very nice	0.9–1.0

3 Experimental analysis

3.1 Experimental scheme

The trial operation plan of hybrid teaching mode was implemented in a university for a period of 10 months. Using this method, the effect of hybrid teaching reform in this university was evaluated, and the changes brought by hybrid teaching mode reform to teachers and students in this university were analysed.

3.2 Experimental data

In this paper, 1000 online samples were obtained through PTA-assisted teaching platform, and 2000 offline samples of the trial operation plan data of the mixed teaching mode of a certain university for 10 months were obtained in the data statistics software. A total of 3000 pieces of fused data were taken as experimental samples, of which 1500 were test samples and 1500 were training samples.

3.3 Selection of performance indicators

In this paper, the evaluation accuracy of teaching reform evaluation method was taken as an experimental index, and its calculation formula is as follows:

$$A_{dm} = \frac{\sum_{i=1}^n H_i - F_i}{N} \quad (11)$$

where A_{dm} represents the evaluation accuracy of the evaluation method; n represents the number of samples of teaching mode reform data; N represents the number of data types; H_i represents the number of qualified samples; F_i represents the number of unqualified samples.

3.4 Testing and analysis of performance indicators

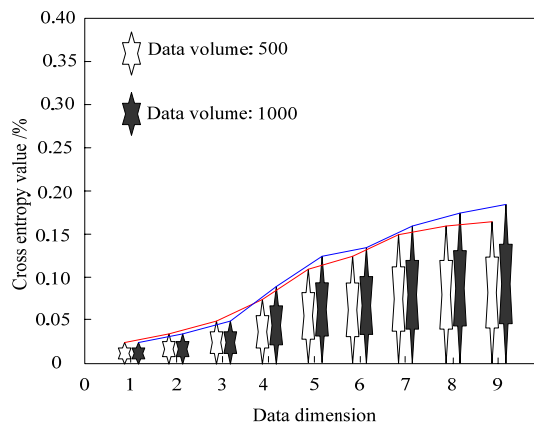
The test plan is to first test the data fusion effect of this method with cross entropy as the indicator, then test the reliability and validity of the indicator system of this method with

Crobach coefficient as the indicator, and finally use the evaluation accuracy as the experimental indicator, using the method proposed in this paper, Zhang (2022) method and Xu (2022) method for comparative testing.

3.4.1 Data fusion test

The fusion of the reform data about hybrid teaching mode is the basis of its effect evaluation. With Cross Entropy as the index to measure the data fusion by this method, the change of cross entropy when the data of hybrid teaching mode reform were fused with different dimensions and quantities. The results are shown in Figure 1.

Figure 1 Data fusion test results of hybrid teaching reform (see online version for colours)

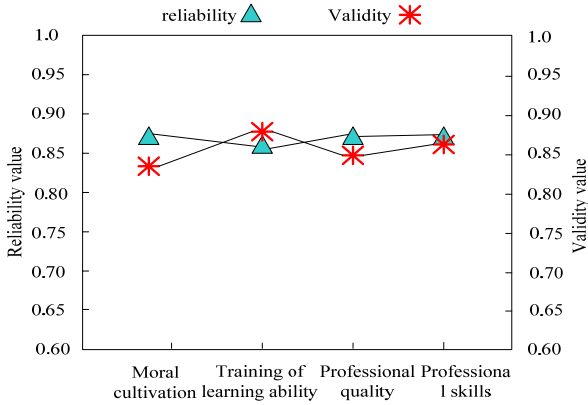


From the analysis of Figure 1, it can be seen that the Cross Entropy value of this method when fusing the hybrid teaching reform data is positively proportional to the data dimension and the number of data. Before the data dimension is 3, the cross-entropy values are exactly the same when the fused data amount is 500 and 1000, and the cross-entropy values increase slightly with the increase of the data dimension. When the data dimension exceeds 4, the cross-entropy value of this method will increase slightly when different data volumes are fused, and the cross-entropy value of 500 pieces of data is slightly higher than that of 1000 pieces of data, but the difference is small, and the maximum cross-entropy value is only about 0.18%. The results show that the proposed method is less affected by data volume and data dimension when fusing the data of hybrid teaching reform, and its cross entropy value is relatively small in the case of fusing the data of hybrid teaching reform, so this method has strong data fusion ability.

3.4.2 Reliability and validity analysis of index system

Taking four first-level indexes as experimental objects, the Cronbach coefficient α was calculated by analysis software, and the results are shown in Figure 2.

Figure 2 Cronbach of reliability and validity of evaluation index system coefficient α (see online version for colours)



According to analysis of Figure 2, there is a small difference between the values of Cronbach coefficient α of the reliability and validity of the first-level indicators of the hybrid teaching reform evaluation index system selected by this method, and the values are all higher than 0.80. The results show that evaluation index of mixed teaching reform selected by this method is more accurate, and the first-level indexes are highly descriptive, so it is more accurate to use them to evaluate the effect of hybrid teaching reform.

3.4.3 Evaluation of hybrid teaching reform

Taking the secondary evaluation index of hybrid teaching reform effect as the experimental object, the method proposed in this paper was adopted to evaluate the learning changes of teachers and students in this university after 10 months of hybrid teaching reform. The results are shown in Table 3.

Table 3 Evaluation results of mixed teaching reform

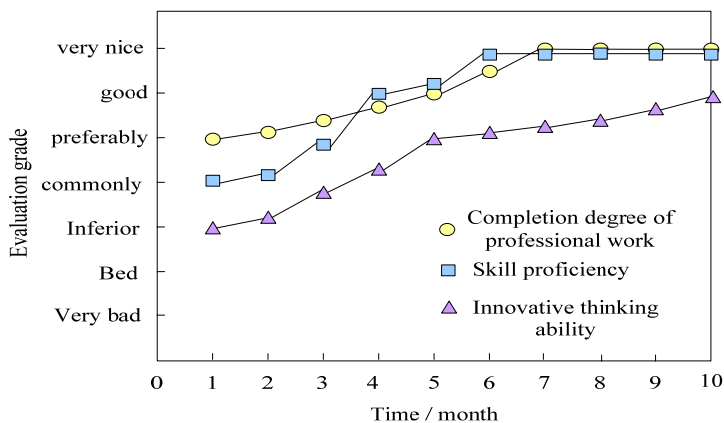
Secondary indicators	Evaluation probability value	Evaluation grade
Integrity	0.73	Preferably
Sense of discipline	0.71	Preferably
Learning attitude	0.75	Preferably
Learning ability	0.82	Good
Innovation ability	0.85	Good
Communication skills	0.92	Very nice
Professional dedication and sense of	0.77	Preferably
Social adaptability	0.86	Good
Mastery of professional knowledge	0.96	Very nice

From the analysis of Table 3, it can be seen that the method proposed in this paper can effectively obtain the probability value after the hybrid teaching reform has been carried out for 10 months, and its evaluation grade can be obtained according to this probability

value. At present, students and teachers in this university are in a good state in terms of integrity, discipline, learning attitude, professionalism and sense of responsibility. The evaluation level of learning ability, innovation ability and social adaptability is good. Students' communication ability with teachers and their mastery of professional knowledge are rated very well. Based on the above results, this paper can effectively evaluate the effect of hybrid teaching reform, so it has a good application effect.

In order to fully present the effect of hybrid teaching reform by method proposed in this paper, professional homework completion, skill proficiency and innovative thinking ability were selected as the evaluation indexes of hybrid teaching reform to improve students' learning effect, and the effect of hybrid teaching reform was analysed. The results are shown in Figure 3.

Figure 3 Effect of mixed teaching reform on improving students' learning (see online version for colours)



According to the analysis of Figure 3, after the hybrid teaching reform, students' professional work completion, skill proficiency and innovative thinking ability have been improved. Among them, when the hybrid teaching reform time was three months ago, the evaluation grades of the three three-level indicators showed a slow upward trend. However, with the increase of the hybrid teaching reform time, the evaluation grades of the three three-level indicators all showed a slightly significant upward trend, among which the completion degree of professional work and skill proficiency generally rose from good at first to very good, while the evaluation grade of innovative thinking ability showed an increasing trend. The above results show that after the hybrid teaching reform in this university, students' abilities in all aspects have been effectively improved, and the hybrid teaching reform has a good effect.

3.4.4 Comparative test of data fusion accuracy

In this paper, the evaluation accuracy of the teaching reform evaluation method was taken as the experimental index, and the methods proposed in this paper, Zhang (2022) and Xu (2022) were used for experimental tests. The test results are shown in Table 4.

Table 4 Fusion accuracy comparison test

<i>Number of experiments/time</i>	<i>Methods in this paper/%</i>	<i>Methods in literature Zhang (2022)/%</i>	<i>Methods in literature Xu (2022)/%</i>
10	96.6	86.0	80.4
20	93.5	86.2	79.2
30	97.1	86.7	79.3
40	96.5	85.4	80.0
50	93.5	84.0	79.3
60	97.4	86.2	79.8
70	95.3	87.0	78.9
80	96.5	86.9	78.5
90	97.6	86.3	79.6
100	93.6	85.2	79.0

According to the results shown in Table 4, the evaluation accuracy of the method proposed in this paper in evaluating the teaching reform is up to 97.6%; that of the method proposed in Zhang (2022) is up to 87.0%, and that proposed in Xu (2022) is up to 80.4%. It can be seen that the evaluation accuracy of the method proposed in this paper is obviously higher than that of the methods proposed in Zhang (2022) and Xu (2022). It shows that the method proposed in this paper can improve the accuracy of teaching reform evaluation, verifying that the method proposed in this paper has high technical level and application value. This is because this method uses support vector machine algorithm to fuse and preprocess multi-dimensional data of mixed teaching reform, which provides accurate and concise data for subsequent evaluation; Based on the principles of measurability and feasibility, a more comprehensive and objective secondary evaluation index system of mixed teaching reform is constructed; The hidden Markov theory is used to evaluate the effect of mixed teaching reform, and the initial distribution probability is creatively introduced to describe the hidden Markov model, thus obtaining a more accurate evaluation of mixed teaching reform.

4 Conclusion

The evaluation method of hybrid teaching reform based on HMM is studied in this paper. HMM is used to evaluate the effect of hybrid teaching reform and realise its evaluation. With a university as the experimental object, the effectiveness of the method proposed in this paper has been verified. The results show that the cross entropy value of this method is small in fusing hybrid teaching reform data of different dimensions and quantities, and the Cronbach coefficient α values of the reliability and validity of the selected evaluation indexes are all higher than 0.8. Moreover, the fusion accuracy of teaching reform data is as high as 97.6%, verifying that the method has strong data fusion ability. In addition, after the application of effective evaluation in hybrid teaching reform, students' professional ability and thinking ability have been improved.

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