Research Article

Cultivation of Students’ Independent Learning Ability in Teaching Chinese as a Foreign Language Based on the CDIO Model of Guiding Data Structures and Hidden Markov Algorithms

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The systematic training of metacognitive strategies in teaching Chinese as a foreign language, cultivating learners’ autonomous learning ability, and improving the effectiveness of teaching Chinese as a foreign language is of great significance for realizing the overall goal of teaching Chinese as a foreign language. Therefore, this paper designs a model based on CDIO to guide the teaching of data structures and algorithms, which emphasizes students’ hands-on ability, advocates learning in use, students’ autonomous learning, and teamwork. Taking massive online open courses (MOOC) and small private online courses (SPOC) learning data as a sample, hidden Markov algorithm and data mining technology are used to establish a student learning behavior evaluation model to evaluate students’ learning behavior in real-time. Meanwhile, teachers adjust the teaching content according to the evaluation results and enhance students’ learning performance and improve teaching quality.

1. Introduction

As the world enters the twenty-first century, with the information age and economic globalization, language science has become more and more important. The rapid development of China’s economy and its international status in the past 20 years, as well as the vast market demand, have forced both developed and developing countries to deal with China for their peace and development and national interests, and their efforts to learn Chinese are also aimed at establishing an in-depth understanding of China [1].

In Asia, Japan has been one of the hottest countries for Chinese language teaching, almost every university has a Chinese language course, and Chinese has become one of the optional foreign languages in the college entrance examination for secondary school students [2]. In South Korea, China’s closest neighbor, more than one million people are learning Chinese, two-thirds of the more than 300 universities have Chinese language courses, and language institutes for learning Chinese are located in all major cities [3].

We can foresee that with the strong development of China and the accelerated development of economic globalization, we can further build a broad bridge of economic and cultural exchanges and people-to-people contact between China and foreign countries [4].

The teaching of Chinese as a second language to foreigners is not only to cultivate the communicative ability of Chinese but also to master the ability to use Chinese to listen, read, write and communicate and to shoulder the responsibility and mission of spreading Chinese culture [5].

Learner-directed learning has become a consensus in the field of language teaching, and learning-centeredness has gradually become the guiding ideology of second language teaching. The learner’s subjectivity has not been fully appreciated and reflected. Only when we shift the focus of our research from “how teachers teach” to “how students learn” can we solve the problem of “how teachers teach” in a targeted way, and only then can we better improve learners’ learning [6]. It is possible to better improve the learning efficiency of learners.
Therefore, in learning Chinese as a foreign language, it is meaningful to study students' learning, focus on learners, and cultivate the learning ability of foreign Chinese learners [7]. In classroom teaching, teachers tend to focus on cognitive strategies that are closely related to specific learning contents and tasks but neglect metacognitive strategy training, which makes it difficult to improve learners’ strategy awareness and strategy application, and may lead to low learning efficiency [8]. The cultivation of learners’ independent learning ability is one of the goals of the effectiveness of teaching Chinese as a foreign language, to achieve the overall goal of the international Chinese teaching curriculum and to realize the international promotion of the Chinese language [9].

A landmark achievement of the CDIO engineering education model is the introduction of the curriculum syllabus. The outline is a guiding document for CDIO engineering education, which specifies the objectives, contents, and specific operating procedures of the CDIO engineering education model in detail. Based on the Hidden Markov Chain Model (HMM), the evaluation index of students’ learning behavior in teaching Chinese as a foreign language is constructed, and the final evaluation score of students’ learning behavior is formed by combining the analytic hierarchy process.

2. Related Work

The ability of self-directed learning can be cultivated through various means. Researchers at home and abroad have been trying to find various ways to cultivate independent learning ability by conducting experiments and studies from various perspectives such as psychology, metacognitive theory, constructivism, and social cognitive theory [10]. At present, in the domestic foreign language teaching English, experts and scholars have commonly studied the cultivation of learners’ autonomous ability, and many teachers, including primary and secondary schools and universities, have conducted research in their teaching practice and achieved good results. Lack of attention to the main role of students in teaching Chinese second language is a problem need to be solved. The independent learning of Chinese language of students can be realized by a new learning pattern of “teacher-led and student-centered combining with equal attention in and out of the classroom” [11–13]. Researchers discussed the necessity of incorporating independent reading outside the classroom into reading instruction and analyzed the effectiveness of this classroom teaching model [14, 15]. The demotivation and motivation study demonstrates that pedagogical means and methods by bridging the gap between researchers and educational practitioners are essential in learning Chinese as a foreign language.

Teachers also need to strengthen instruction in learning strategies in a variety of ways. Teachers should present a range of learning strategies that students must master for them to understand and use [16]. The following are common approaches that teachers can use in teaching a second foreign language. Teachers can guide students to develop specific, detailed plans and identify specific activities and schedules related to their learning goals. They can also guide students to write down their learning process, methods, and experiences in a variety of appropriate ways, to self-evaluate and self-monitor their learning and to adjust their learning methods and strategies for the next stage accordingly [17, 18]. When doing exercises, pay attention to the ideas and techniques for solving various types of frequently tested questions and learn and master test-taking strategies and methods. Teachers should also guide students to make full use of resources, learn to create and grasp opportunities to use the target language, be good at using body language to improve the communicative effect, and guide the use of Internet resources for learning [19].

In this paper, a CDIO-based model is designed to guide the teaching of data structures and algorithms. Taking the MOOC + SPOC learning data of our school as a sample, the hidden Markov algorithm and data mining technology are used to establish a student learning behavior evaluation model and real-time evaluation of students’ learning behavior. Learning behavior: teachers adjust teaching content according to the evaluation results and intervene in students’ learning behavior to improve teaching quality. That is, it emphasizes students’ practical ability and advocates learning by doing students’ independent learning, and teamwork.

3. The Guiding Principle of the CDIO Model in Teaching

The CDIO model for teaching data structures and algorithms is based on how to combine the course with practical cases to improve students’ hands-on skills. The main aspects are as follows.

3.1. Emphasis on Practical and Hands-On Skills. The main idea of the CDIO model is to focus on practice and operation. Only when the teaching data structure and algorithm is combined with actual cases the practical and hands-on ability can be reflected under the guidance of theory. A large number of cases will greatly improve the practical and hands-on ability [20].

3.2. Promote Independent Learning and Problem Solving. The CDIO model is a prerequisite and foundation for developing students’ independent skills, and we should strive to improve the efficiency of teaching data structures and algorithms. Generally speaking, it is possible to use to arrange students’ independent learning by listing knowledge points. Teachers must master the main points of knowledge and recommend some required reading to students, while students are required to track themselves and read the literature. One can also learn to learn by comparison. Encourage students not to blindly believe in textbooks but to understand why this view is mainstream and classical and why all other views are gradually being eliminated in practice, by actually comparing them to what was thought at the time and what was the way of understanding without distinction. The most important thing is the brainstorming method. The teacher participates equally in the students’
discussion and addresses a point of knowledge, and teachers and students freely present their views, allowing students to analyze themselves afterward, stimulating their thinking, and deepening their understanding of the point.

3.3. Professional Competence and Teamwork. The model recognizes the imbalance of competencies in the study team and emphasizes the best model to equip the study team to explore the competencies of the students. During learning and discussion, group members’ performance should be recorded, and the best organizers and implementers should be selected through three to five rounds of observation of student readiness and mutual assessment. In a research team, it is not only important to ensure that the research direction does not deviate but also to allow members to have a process of meeting ideas, through debate, so that new ideas and new thoughts can be generated, taking into account economic performance, social impact, simplifying and streamlining as much as possible, emphasizing user interface intuition and ease of operation.

4. Research Framework

The assessment of student learning behavior status in this study was based on data from student learning trajectories on the MOOC + SPOC platform. HMM was used to obtain the student learning status matrix, and then the scores were calculated based on the learning behavior data evaluation method, i.e., the corresponding learning evaluation scores. Historical judgment data of more than two consecutive weeks are retained, and student learning state trends and continuous period student learning behavior evaluation scores are calculated based on these data. The HMM algorithm is used to map the observed student learning state data to hidden state trends, and the Viterbi algorithm is used to solve for future time student learning behavior change trends and learning evaluation scores. The hidden state and continuous period of student learning behaviors are used as inputs for the process shown in Figure 1.

4.1. Framework Model HMM Model. Since students’ learning states are more likely to be disturbed by various factors, such as the surrounding environment, psychological state, physiological cycle, and many other factors, this makes the change of students’ learning states a typical random process. At the same time, the change in students’ learning state is generally associated with the state of the previous period only. If it is determined by the previous state only, it is a first-order Markov model, and if it is influenced by several previous time states at the same time, it is an n-order Markov model. In Reference [21], a Markov model describes an important class of stochastic processes, which is a stochastic function that varies with time.

In a Markov model, each state represents an observable event, which limits the use of the model to certain states where the event is not easily observable [22]. For teaching, a teacher may want to determine the next state of a student’s learning behavior by looking at the student’s online learning, questioning, and correctness of assignments when the next state is not yet present. This algorithm is known as HMM which predicts students’ next learning state by observing their usual learning process data and the Markov hypothesis. [23].

One of the basic assumptions in HMM model is the assumption of the chi-square Markov chain, that is, the hidden state at any moment depends only on the hidden state at the previous moment.

The model obtains the probability of each observation by the current state where \( b_{ij} \) represents the probability that at any moment \( t \), if the state is \( S_i \), then the observation is \( O_j \).

There are three problems in the HMM model: first is the evaluation problem, given an HMM, i.e., \( \lambda = [A, B, \pi] \), to calculate the probability of sequence; second is the decoding problem, given an HMM, i.e., \( \lambda = [A, B, \pi] \), to find the optimum sequence of states to a sequence of observations.

For the problem of early prediction and timely intervention of students’ learning behavior, it is the learning problem and decoding problem of HMM. The learning problem is solved by the EM algorithm, and the decoding problem is solved by the Viterbi algorithm based on dynamic programming. Using the parametric model \( \lambda = [A, B, \pi] \) derived from the EM algorithm and the existing observed sequence of student learning states \( O = \{O_1, O_2, \ldots, O_T\} \), the most likely sequence of student learning behavior states \( I^* = [i_1^*, i_2^*, \ldots, i_T^*] \), i.e., \( P(I^*|O) \) is to be maximized under the given conditions.

4.2. Evaluation Indexes of Student Learning Behavior Analysis. According to the construction ideas and methods of online teaching quality evaluation indexes at home and abroad, the overall evaluation indexes are divided into 2 primary indexes and 6 secondary indexes, as shown in Table 1.

The matrix was constructed using hierarchical analysis to obtain the weights. The indicators at the same level were assigned with the Starr relative importance scale (9 levels) to form a judgment matrix. Take the secondary index of learning attitude as an example, Table 2 shows its importance scale, in which the parameter levels are obtained from student questionnaires and expert ratings in reference literature [24–26].

The single-sort judgment matrix is obtained at this level:

\[
B = \begin{bmatrix}
1 & 1/5 & 1/3 & 1/3 \\
5 & 1 & 3 & 2 \\
3 & 1/3 & 1 & 2 \\
3 & 1/2 & 1/2 & 1
\end{bmatrix}.
\]  

Due to possible biases in perceptions, the design of student learning behavior index weights may have inconsistent biases. Therefore, we conducted a consistency test based on the hierarchical analysis method (AHP). The test formula is as follows:
where \( RI \) is the average random consistency index (see Table 3 for the values of \( RI \)).

When \( CR \leq 0.1 \), it means that the consistency test is passed and the design can be carried out according to the results of the matrix representation; when \( CR > 0.1 \), it means that the deviation of the judgment matrix is too large and there are contradictions in the process, and the scoring needs to be modified and reconstructed until the consistency is satisfied.

The key to the study of learning behavior analysis is as follows: first, to score the indicators for evaluating learning behavior in order to obtain the current state (current week) learning behavior evaluation; second, to obtain the related behaviors (such as learning attitude, learning initiative, and learning effect) that reflect the learning behavior state in order to judge the trend of learning state change and then to predict the learning behavior state change according to the HMM model [28]. The formulation of this problem in the Hidden Markov Model for each parameter variable set is as follows.

5. Research Object

The key to the study of learning behavior analysis is as follows: first, to score the indicators for evaluating learning behavior in order to obtain the current state (current week) learning behavior evaluation; second, to obtain the related behaviors (such as learning attitude, learning initiative, and learning effect) that reflect the learning behavior state in order to judge the trend of learning state change and then to predict the learning behavior state change according to the HMM model [28]. The formulation of this problem in the Hidden Markov Model for each parameter variable set is as follows.

Learning attitude state set

\[ I_s = \{ i_1 = \text{“Active”}, i_2 = \text{“General”} \} \]  \hspace{1cm} (3)

Learning initiative state set

\[ I_a = \{ i_1 = \text{“Proactive”}, i_2 = \text{“Passive”} \} \]  \hspace{1cm} (4)

Learning effect status set

\[ I_r = \{ i_1 = \text{“Good”}, i_2 = \text{“General”} \} \]  \hspace{1cm} (5)

Table 2: Importance ranking of secondary indicators of learning attitudes.

| Primary indicators | Secondary indicators | Evaluation criteria |
|--------------------|----------------------|---------------------|
| Learning attitude  | Course access        | Number of visits to the course platform |
|                    | Course learning      | Length of course study, length of videos watched |
|                    | Online interaction   | The number of effective postings and discussions by students |
|                    | Interaction with teachers | Students’ questions, teachers’ answers, and discussions |
| Professional ability | Assignment completion rate | The ratio of the number of completed assignments to the total number of assignments |
|                     | Assignment pass rate | The ratio of the number of graded homework questions to the total number of questions |

Table 1: Overall evaluation indexes of learning behavior.

| Primary indicators | Secondary indicators | Evaluation criteria |
|--------------------|----------------------|---------------------|
| Learning attitude  | Course access        | Number of visits to the course platform |
|                    | Course learning      | Length of course study, length of videos watched |
|                    | Online interaction   | The number of effective postings and discussions by students |
|                    | Interaction with teachers | Students’ questions, teachers’ answers, and discussions |
| Professional ability | Assignment completion rate | The ratio of the number of completed assignments to the total number of assignments |
|                     | Assignment pass rate | The ratio of the number of graded homework questions to the total number of questions |

\[
CR = \frac{CI}{RI} \hspace{1cm} (2)
\]
Learn the active event set:

\[ O_a = \begin{cases} 
  o_1 = 1 & \text{“number of proactive and answer session, interactions”} \geq c_1 \\
  o_2 = 1 & \text{“number of proactive and answer session, interactions”} < c_1 
\end{cases}. \tag{6} \]

Learning effect event set:

\[ O_e = \begin{cases} 
  o_1 = 1 & \text{“assignment test scores”} \geq d_1 \\
  o_2 = 1 & \text{“assignment test scores”} < d_1 
\end{cases}. \tag{7} \]

In the specific experimental process, first, the data were transformed into a learning attitude dataset, learning initiative dataset, and learning effect dataset according to the definition of the observed dataset; then, the parameters of the student learning behavior model were obtained using the observed dataset in weeks 1–5 using the EM algorithm, and the obtained parametric model was applied to the observed dataset in weeks 6–9 for model validation. The model parameters and observed student data were then used to predict student learning behaviors over the next 10–15 weeks, and the weekly predictions were used to disrupt some students’ learning [29, 30].

### 6. HMM Model Parameters Calculation

The solution to HMM model parameters is divided into two cases. The EM iterations are then performed until the values of the model parameters converge. The algorithm proceeds as follows:

One is to randomly initialize all \( \pi, a_{ij}, b_j(k) \).

Second, for each sample \( d = 1, 2, \ldots, D \), the backward and forward algorithm is used to compute \( r_1^{(d)}(i), \theta_t^{(d)}(i, j), t = 1, 2, \ldots, T \).

Third, update the model parameters:

\[
\pi_i = \frac{\sum_{d=1}^{D} r_1^{(d)}(i)}{D},
\]

\[
a_{ij} = \frac{\sum_{d=1}^{D} \sum_{t=1}^{T-1} \theta_t^{(d)}(i, j)}{\sum_{d=1}^{D} \sum_{t=1}^{T-1} \theta_t^{(d)}(i)}.
\]

\[
b_j(k) = \frac{\sum_{d=1}^{D} \sum_{t=1}^{T-1} \theta_t^{(d)}(i) \pi_k r_1^{(d)}(i)}{\sum_{d=1}^{D} \sum_{t=1}^{T-1} r_1^{(d)}(i)}.
\]

Fourth, if the value of \( \pi, a_{ij}, b_j(k) \) has converged, the algorithm is finished; otherwise, go back to the second step to continue the iteration.

The HMM parameters \( \pi, A, \) and \( B \) of learning attitude, learning initiative, and learning effect obtained by iteration are shown in Table 5.

### 7. Experimental Results

The prediction results of the scheme in this paper are shown in Table 6, where \( W_6, W_7, W_8, \) and \( W_9 \) denote weeks 6, 7, 8, and 9, and the values in Table 6 are the probabilities of transferring states.

The prediction results obtained from the model were compared with the actual student results in weeks 6–9. Figure 2 shows the comparison of the HMM prediction results. The learning motivation prediction result shows that the HMM misfit rate is 3%, the learning method prediction result shows that the HMM misfit rate is 2.668%, and the learning effect prediction result shows that the HMM misfit rate is 1.335%.
The validity of the model was judged by the consistency of the results. Students’ scores were calculated according to the weights of student learning behavior evaluation indexes, and the predicted results were verified with the actual results for consistency, and the calibration results are shown in Table 7.

The validation analysis of the model shows that the HMM prediction model established in this paper has a certain validity.

After 4 weeks, the learning behaviors of the two groups were compared and analyzed to see if the performance of the group of students who had been disturbed by the teacher improved compared to the group of students who had not been disturbed by the teacher. The results of the learning evaluation comparison shown in Table 7, where the learning evaluation scores were calculated based on the learning evaluation indicators, and demonstrate effective improvement of students’ Chinese learning performance.

### Table 5: HMM model parameters.

|                        | \( \pi = [01] \), \( A = \begin{bmatrix} 0.68 & 0.32 \\ 0.57 & 0.43 \end{bmatrix}, B = \begin{bmatrix} 0.84 & 0.16 \\ 0.22 & 0.78 \end{bmatrix} \) |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Learning attitude      | \( \pi = [01] \), \( A = \begin{bmatrix} 0.85 & 0.15 \\ 0.19 & 0.81 \end{bmatrix}, B = \begin{bmatrix} 0.76 & 0.24 \\ 0.21 & 0.79 \end{bmatrix} \) |
| Learning initiative    | \( \pi = [01] \), \( A = \begin{bmatrix} 0.91 & 0.09 \\ 0.10 & 0.90 \end{bmatrix}, B = \begin{bmatrix} 0.82 & 0.18 \\ 0.25 & 0.75 \end{bmatrix} \) |

### Table 6: HMM prediction results.

| Predicted results     | W6           | W7           | W8           | W9           |
|-----------------------|--------------|--------------|--------------|--------------|
| Learning attitude     | 0.69/0.35    | 0.6427/0.3449| 0.6355/0.3585| 0.6327/0.3575|
| Learning initiative   | 0.89/0.17    | 0.7512/0.2497| 0.6862/0.3145| 0.6431/0.3587|
| Learning effectiveness| 0.92/0.12    | 0.8287/0.1632| 0.7539/0.2213| 0.6862/0.2672|

### Table 7: Comparison of calculation results.

|                  | 1–5 weeks | 6–9 weeks |
|------------------|-----------|-----------|
| Average of predicted results | 77.9 | 79.85 |
| Average of actual results       | 84.22 | 85.69 |
| Consistency                  | 91.97% | 93.56% |

### 8. Conclusion

In this paper, the evaluation indexes of students’ learning behaviors in teaching Chinese as a foreign language were constructed based on the Hidden Markov Chain Model and combined with the hierarchical analysis method to form the final evaluation scores of students’ learning behaviors. Based on the comprehensive scores, we determine the current state of students’ learning behavior, predict the trend of students’ learning behavior changes with the help of the Hidden Markov Model, and realize the early warning of students’ learning behavior state, so that teachers can take disturbing measures in time to achieve the purpose of dynamic monitoring and improving students’ learning state.

### Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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