



The effect of classroom interaction patterns on the development of students' thinking in basic education at the primary level

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SUMMARY: *The characteristics of teacher-student verbal interaction behavior in elementary school basic teaching will affect the teaching effect to a certain extent, and this paper uses speech recognition technology to technically empower the analysis of classroom interaction behavior. The ResNet-34 model is used for speech subject recognition, and the loss function AAM-Softmax is introduced to obtain highly distinguishable angular features. With the help of the amplitude spectrum and phase spectrum of the signal as the feature values, the model recognition ability is improved. Taking the elementary school classroom interaction between teachers and students as the research object, based on the iFIAS method for observation, the classroom observation results are analyzed. A teacher's classroom 2 increased the total number of positive integration zone times by 6 compared to classroom 1, and the number of defective frames decreased to 6. At the same time, the number of steady-state zones (10, 10) reached 105, and the frequency of students' discussion was effectively increased. In the practical post-test, each class contained 2~3 higher-order thinking skills, and the proportion of students' practical ability to master the ability to find problems increased by 58%, which shows that the technology-enabled classroom interactive teaching mode can promote the development of students' higher-order thinking.*

KEYWORDS: *speech recognition technology; classroom interaction analysis; ResNet-34 model; iFIAS; thinking development*

1 Introduction

As far as elementary school students are concerned, they are at the time of developing learning thinking and good learning habits. Unlike the subsequent stages of students whose main task is to learn basic knowledge, in primary education, the most important teaching task of teachers is to guide students to develop good learning habits and learning mindsets [1, 2]. If students fail to develop good learning habits and learning thinking in elementary school, they will be more difficult to learn in the future. Therefore, all teachers in primary education should recognize the importance of cultivating students' good learning habits and learning mindsets, and implement them into the whole process of education and teaching [3].

On July 24, 2021, China issued the Opinions on Further Reducing the Burden of Homework for Students in Compulsory Education and the Burden of Out-of-School Training, or the “Double Reduction Policy,” which explicitly states that the quality of classroom teaching should be improved, and the efficiency of students' learning at school should be increased [4]. In essence, the concern and implementation of the “double-decrease” policy is to pay attention to “what kind of people education should cultivate” and “how to cultivate people's problems”,

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is the comprehensive implementation of the party's education policy. It is a matter of fully implementing the party's education policy and realizing the issue of establishing moral education [5]. The essence of the “double-decrease” policy is to implement the fundamental task of establishing morality and educating people, and this goal drives educational reforms in schools, which have become the main position for the effective implementation of the “double-decrease” policy [6, 7]. Classroom teaching is the center of school education, therefore, the implementation of the fundamental task of “cultivating moral integrity” must take the classroom as a favorable grip [8].

An in-depth examination of classroom teaching in China reveals that there is a widespread problem of “avoidance of learning” or “false learning” among students, which is a hidden crisis in China's educational development and a threat to the future development of talent bottlenecks. Although the current education reform in China involves the classroom level, from the actual situation, the classroom transformation of basic education is difficult, and the high quality of students' learning is not guaranteed [9]. In order to avoid students learning too easy or too difficult content in the classroom, it is necessary to improve the efficiency and quality of students' classroom learning within a reasonable range, so that students can “learn enough and learn well” in school, which requires continuous improvement of the overall effect of classroom teacher-student interaction [10, 11].

Interactive teaching mode was firstly proposed by American educational psychologists Brown and Palinsa, the main purpose of this teaching mode is to improve the teaching method of students' reading comprehension and self-learning ability, which is developed on the basis of scaffolding teaching theory [12, 13]. Interactive teaching mode refers to a teaching mode that develops students' creative thinking and cultivates their learning ability by adopting learning methods such as dialogues, seminars and exchanges between teachers and students under the inspiration and guidance of teachers to form an interactive learning mechanism [14-16]. Based on this background, academic literature reports related to interactive teaching mode are analyzed to provide strong guidance for this study.

On the one hand, interactive teaching enhances learning in disciplinary education. Literature [17] observed classrooms with teacher-student interactions in majors including natural sciences, management, economics, medicine, engineering, and humanities, explored the effects of classroom teacher-student interactions on students' self-efficacy, and obtained the conclusion that self-efficacy of students with teacher-student interactions was positively correlated. Literature [18] investigated the intervention effects of interaction modes in a language learning classroom on students' adaptability and learning efficiency, and through a classroom survey, it was found that the most commonly used interaction modes in the classroom were teacher-student interactions, and that educators were able to make additional pedagogical suggestions based on the learning effects brought about by teacher-student interactions. Literature [19] reformed the traditional English teaching model by integrating the human-computer interaction teaching system into the English classroom, which dramatically improved students' English learning effectiveness, including a 26% increase in classroom knowledge mastery, a 27% increase in the correct rate of English application skills, and a corresponding 25% increase in intercultural communication skills. Literature [20], on the other hand, applied the interactive teaching model in the physical education classroom of Muhammadiyyad High School No. 57 and compared the changes in students' dribbling ability before and after the interactive teaching, which showed a linear increase in the students' dribbling learning effectiveness with the increase in the length of the intervention of the interactive teaching model.

On the other hand, students' thinking ability was developed. Literature [21] points out that the smart classroom integrating science and technology and education is an inevitable trend of educational development, and the effect of teacher-student interaction under the smart

classroom can improve students' inquiry ability, independent learning ability, thinking ability, and realize the comprehensive cultivation of innovative and intelligent talents. Literature [22] investigated the views of 194 students and staff on virtual classroom teaching, virtual classroom as a product of the intelligent era for is a powerful medium for classroom interaction, peer interaction teaching mode can effectively motivate students to participate in the classroom and develop their thinking ability. Literature [23] used virtual reality technology to independently design a human-computer interaction learning system, the construction of the virtual teaching environment for teacher-student interaction or student-student interaction to provide a powerful condition, the student's satisfaction with the system is higher, with greater practicability and feasibility. Literature [24] used discourse analysis to code 73 interactive dialogues between teachers and students in elementary school mathematics, aiming to study the correlation between the type of teacher's question and answer and students' thinking development, and finally found that the interactive question and answer mode between teachers and students can effectively improve students' thinking. In summary, it is found that there is no fixed model for interactive teaching mode in academics, but it is certain that teachers, students, teaching content and teaching environment are all essential components in this mode.

In this paper, the deep residual network ResNet-34 is used as a pre-training model for speech recognition, and an improved optimization strategy for the Softmax loss function is proposed. The loss function is adjusted using additive angular intervals to improve the speech subject recognition ability of the model. The improved Flanders interaction analysis system is selected as an observation tool to assess the level of classroom interaction through matrix and ratio analysis. Three elementary schools in City A were used as the research sites to carry out technology-enabled classroom interaction teaching practice. The model of this paper was used for active voice detection to analyze students' classroom interactive behaviors. Students' higher-order thinking learning outcomes and the implementation effects of the technology-enabled classroom interaction teaching model were analyzed through pre and post-test comparisons.

2 Methodology for analyzing classroom interactions combining neural networks and the Flanders system

2.1 Neural network-based classroom speech subject recognition

2.1.1 Loss function

(1) Softmax function

Improvements to the model structure can improve the detection ability of the model, while improvements to the loss function can help the model fit better during learning and training. Traditional voiceprint recognition neural network systems use a Softmax loss function to evaluate the model after the fully connected layer. The Softmax loss function here actually refers to the joint function of the Softmax classification function and the cross-entropy loss function, and its specific calculation process can be expressed as follows:

$$L_s = \frac{1}{N} \sum_{i=1}^N -\log \frac{e^{W_{y_i}^T x_i + b_{y_i}}}{\sum_{j=1}^C e^{W_j^T x_i + b_j}} \quad (1)$$

where C of the above equation represents the number of classification categories during model training, N is the number of samples, x_i is the input of the fully connected layer after

the i th sample, while y_i refers to the feature labels of the i th sample, and W_j, b_j represent the weight and bias values of the classification layer for the j th classification, respectively.

(2) L-Softmax loss function

Since the Softmax function is not effective for optimization of intra-class distance and intra-class discrimination, the L-Softmax function is proposed to further subdivide the feature information. Unlike the original Softmax function, the samples and parameters in the original calculation process can be categorized into the following forms:

$$W_j^T x_i = \|w_j\| \|x_i\| \cos(\theta_{i,j}) \quad (2)$$

where $\theta_{i,j}$ is the angle between w_j and x_i . By this transformation, the L-Softmax function allows for greater angular separability between the vectors. More specifically, the function introduces a positive integer m to further constrain the decision boundary for binary classification. For example, there is an existing sample x from categorization 1, and the decision boundary of the original Softmax function is:

$$\|w_1\| \|x\| \cos(\theta_1) > \|w_2\| \|x\| \cos(\theta_2) \quad (3)$$

And in L-Softmax, the authors propose the idea of determining intervals that require:

$$\|w_1\| \|x\| \cos(m\theta_1) > \|w_2\| \|x\| \cos(\theta_2) \quad (4)$$

The θ_1 in Eq. satisfies $\left(0 \leq \theta_1 \leq \frac{\pi}{m}\right)$, which is a tighter restriction that makes the correct classification of Classification 1 more accurate.

(3) A-Softmax loss function

A-Softmax is similar to the basic structure of L-Softmax and also employs a function to separate the samples from the parameters in the original equation, as well as introducing a positive integer m to control the angular spacing. A-Softmax normalizes its weight parameter W , which gives a different meaning to A-Softmax and L-Softmax in terms of geometric interpretation.

(4) AM-Softmax loss function

The additional interval loss function AM-Softmax changes the original multiplicative factor to an additive factor, $\cos(\theta) - m$, which changes the angular relationship to a comparison of cosine values. In addition to this, a hyperparameter s is set to scale the cosine values, which further speeds up the convergence of the model, and the final AM-Softmax loss function is defined as:

$$L_{AMS} = \frac{1}{N} \sum_{i=1}^N -\log \frac{e^{s(\cos(\theta_{y_i}) - m)}}{e^{s(\cos(\theta_{y_i}) - m)} + \sum_{j=1, j \neq y_i}^C e^{s(\cos(\theta_j))}} \quad (5)$$

(5) AAM-Softmax Loss Function

After investigation and research, it was found that angular distance has a more significant effect on angle than cosine distance, so the Additive Angular Interval Loss Function (AAM) adds the interval to the angle θ to additively adjust the angle between a deep feature and its corresponding weight, thus simultaneously enhancing the tightening of features within the same

class and the distinction between different classes. The algorithm utilizes the transformation of cosine values and angles, hence the name Arc-Softmax.

The normalized input feature values and the normalized weight parameters are fork multiplied to obtain a cosine value, and this value is inverted with an inverse function to obtain the corresponding angle θ , and then the interval m is added to this θ , and the new cosine value is processed by a feature scaling function to be output. The final formula is as follows:

$$L_{Arcs} = \frac{1}{N} \sum_{i=1}^N -\log \frac{e^{s(\cos(\theta_{y_i} + m))}}{e^{s(\cos(\theta_{y_i} + m))} + \sum_{j=1, j \neq y_i}^C e^{s(\cos \theta_j)}} \quad (6)$$

From the above process derivation, it can be learned that compared to the previous loss function, AAM-Softmax puts the interval parameter inside the cosine function, which makes the computation process convenient and fast and does not affect the function's classification of features.

2.1.2 Eigenvalue calculation

After the above pre-processing of the speech signal, feature extraction of the human voice will be performed, i.e., obtaining speech key information from the speech signal. The traditional vocal features are Mel Frequency Cepstrum Coefficient (MFCC), Fbank features, etc. Among them, MFCC adjacent frame features are relatively independent, and the information contained in the continuous speech signal may be lost.

After obtaining the frequency domain signal after short-time Fourier transform, the following operations are also required in order to obtain the MFCC features:

(1) Mel filter bank: the Fourier transformed spectrum is passed through a filter bank $H_m(k)$, which allows the amplitude of the frequency domain to be streamlined, with each frequency band represented by a single value.

$$H_m(k) = \begin{cases} 0, & k < f(m-1) \\ \frac{2(k-f(m-1))}{(f(m+1)-f(m-1))(f(m)-f(m-1))}, & f(m-1) \leq k \leq f(m) \\ \frac{2(f(m+1)-k)}{(f(m+1)-f(m-1))(f(m)-f(m-1))}, & f(m) \leq k \leq f(m+1) \\ 0, & k \geq f(m+1) \end{cases} \quad (7)$$

where $f(m)$, $m = 1, 2, \dots, M$, is the center frequency, M usually takes the value range of 22-26 and $\sum_{m=0}^{M-1} H_m(k) = 1$.

(2) Logarithmic operation, $\log \log$ nonlinear relationship can better describe the perception of the sound, logarithmic operation followed by cepstrum analysis, the formula is as follows:

$$S(m) = \ln \left(\sum_{k=0}^{N-1} |X_a(k)|^2 H_m(k) \right), 0 \leq m \leq M \quad (8)$$

When this step is carried out, the Fbank features have been obtained, and in order to remove the correlation between the dimensional signals, MFCC will further process the results.

(3) Discrete Cosine Transform (DCT), compresses the speech signal to obtain the low frequency information of the frequency spectrum as shown in the following equation:

$$C(n) = \sum_{m=0}^{N-1} s(m) \cos\left(\frac{\pi n(m-0.5)}{M}\right), n = 1, 2, \dots, 16 \quad (9)$$

Inevitably, non-speech information will be mixed in the speech of the classroom. Moreover, due to the complexity and variability of factors within the classroom environment (e.g., environmental noises, multi-person speech, equipment noises, etc.), using only the noise data from a certain type of environment for noise cancellation processing will in turn lead to a decrease in the generalization ability of the model. Meanwhile, the feature extraction steps such as MFCC or Fbank will delete the information in the speech signal that is considered useless for recognition, which will have an impact on the training of the neural network.

In contrast, the use of features with magnitude and phase spectra can retain the information contained in the vocal speech signal in a more complete manner, and reduce the amount of computation, simplifying the subsequent training process of the neural network. In order to give full play to the ability of the deep residual network in model matching, this paper does not use the MFCC or Fbank features for distinguishing the speaker, but first preprocesses the speech signal, and adopts the magnitude spectrum and phase spectrum obtained after the signal is short-time Fourier transformed as the input of the voiceprint recognition algorithm.

In summary, this paper uses the magnitude spectrum and phase spectrum as the voiceprint feature values of the speaker in the classroom. Meanwhile, this paper utilizes cosine similarity for pattern matching of different feature vectors. The magnitude spectrum and phase spectrum are utilized to obtain the feature vectors of different speech segments, and then the degree of similarity between different segments is evaluated. For example, the cosine similarity between speech vectors can be expressed by the following equation:

$$\cos \theta = \frac{\sum_{i=1}^n x_i y_i}{\sqrt{\sum_{i=1}^n x_i^2} \times \sqrt{\sum_{i=1}^n y_i^2}} \quad (10)$$

As the cosine similarity between two vectors gets closer to 1, it means that the angle between the two vectors gets closer to 0° , in other words, the two speech segments are more similar and more likely to come from the same speaker.

2.2 iFIAS-based classroom observation

iFIAS categorizes teacher-student interactions during the teaching and learning process into three main categories: the teacher's verbal expression, the student's verbal response, and silence or chaos. iFIAS's code system consists of fourteen different codes, and this paper further elaborates on the fourteen subcategories of codes:

Coding 1 Teacher Acceptance of Emotions: understanding and clarification of both positive and negative student expressions without criticism or coercion due to changes in student emotions.

Coding 2 Teacher Praise or Encouragement: the teacher's way of affirming and motivating students, while also covering their silence in the face of classroom communication challenges.

Coding 3 Teacher adopts students' viewpoints: the teacher organizes, explains, or agrees with students after they have articulated their viewpoints, and this includes ways such as directly repeating students' answers.

Coding 4 Teacher questioning: the teacher asks the following two types of questions: open-ended questioning and closed-ended questioning.

Coding 5 Teacher lecture: the teacher explains the content of the material or the students' expressions and explains his/her opinion.

Coding 6: In the classroom, as the controller, the teacher needs to organize the upcoming session, including guiding and prescribing students' behavior.

Coding 7 Teacher's criticism or protection of authority behaviors, common in moments of classroom chaos, which are statements and actions taken by the teacher out of a desire to maintain order in the classroom.

Coding 8 Student Passive Response: students respond, usually passively, to questions from the teacher, followed by a roll call or instructions based on a certain sequence.

Coding 9 Student Active Response: students' active speaking covers their autonomous responses and questioning; when the teacher asks a question, these students provide their own answers or raise their hands to ask.

Coding 10 Student Discussion: Students allocate time in the classroom in an orderly manner so that they are free to engage in discussions with their peers.

Coding 11 Instructional disorganization issues: disorganized chaos that is not essential to the classroom.

Coding 12 Helpful Silence for Teaching and Learning: a classroom that helps students to pause and be silent so that they can be prompted to think and assimilate knowledge.

Coding 13 Teacher manipulation of technology: teachers communicate their ideas accurately by utilizing the multimedia tools of the online platform.

Coding 14 STUDENT OPERATING TECHNOLOGY: Students enhance their participation in the classroom by utilizing the multimedia tools available on the online platform to enhance their technical communication with the teacher.

The iFIAS coding system was used to convert classroom videos in three-second intervals, coding each interaction within the three-second period according to the coding instructions and recording them.

2.2.1 Matrix analysis

The IFIAS assessment form is a symmetrical matrix of size 14 x 14, containing rows one through seven for teacher speech actions and rows eight through ten for student discourse actions; it is reasonable to compare these numbers to gauge the degree of educational balance in the classroom - if the former is more prevalent than the latter, then this means that the lesson is If the former is higher than the latter, then this means that the lesson is mainly controlled by the teacher rather than the students' initiative, while on the other hand, if the ratio is similar or skewed towards the latter rows, it means that they are effectively involved and deeply integrated in the learning process, which is in line with the concept of learning that emphasizes the learner's autonomy.

For students, the impact of the teacher's language can be categorized into two types: indirect and direct. The ratio of the two helps to assess the teacher's approach to education. If this ratio is higher than 1, then it indicates that the teacher is more adept at guiding the students in an indirect way; conversely, this may mean that the teacher favors directing them. Regarding how teachers motivate students, we can look at two aspects: one is positive encouragement and the other is negative stimulation. As for the classroom atmosphere, it is reflected in an emotional reaction that the teacher creates with the students during the lecture.

2.2.2 Ratio analysis

For the frequency of teacher language use, this ratio is measured by dividing the total number of codes used by the teacher by the overall number of all codes used, with a larger value implying that the teacher speaks more in the classroom, and it has a norm-referenced value of 68%. The proportion of students influenced by the teacher through indirect means can be derived by dividing the total number of occurrences of codes in categories 1 through 4 by the total number of occurrences of codes in categories 5 through 7, and the norm-referenced ratio may be higher or lower than 100%.

For teacher questioning, we measured this by first counting the sum of the number of questions in the four categories and the number of questions in categories from 4 to 5; this ratio value was then used to assess the percentage of all questions asked by the teacher during the lecture, i.e., the percentage of the total number of times they asked questions in relation to the total number of contents explained. For students' autonomous engagement, this ratio was derived from the following formula: the ratio of the number of 9 categorical codes to the sum of 8 to 9 categorical codes. This reflects the proportional relationship between the frequency with which students actively express their opinions and their overall frequency of discourse. If this indicator is high, it suggests that they are more willing to share their ideas in the classroom.

3 Design of a study on classroom interaction behavior in basic education at the primary level

3.1 Subjects of study

The basic statistics of the classroom observation subjects are shown in Table 1. At the beginning of the study, we communicated with several elementary school in City A. Finally, P1, P2 and P3 elementary school agreed to provide support for the study, and therefore, the above three schools were finally taken as the observation schools in the study.

In order to avoid the influence of school factors on teacher-student verbal interactions in classroom teaching, and to avoid the bias of the observation results due to the different number of classroom observation subjects from each school, the same number of subjects was observed in each school during the screening of classroom observation subjects, and five elementary school teachers were selected from each of the three schools identified for observation, resulting in the total number of elementary school teachers observed being 15. The total number of primary school teachers observed was 15. In order to avoid the influence of teachers' seniority on the verbal interactions between teachers and students in classroom teaching, and to avoid the situation that the number of classroom observation subjects with different seniority varies too much, which may lead to the bias of observation results, we insisted on the principle of balancing the distribution of seniority as much as possible when selecting the classroom observation subjects, and there were 5 novice, 5 skilled and 5 expert elementary school teachers among the 15 elementary school teachers under observation in the final study.

Table 1: Basic information of classroom observation objects

Statistical entries	Group	Number of people	Percentage/%
School	P1	50	33.33
	P2	50	33.33
	P3	50	33.33
Gender	Male	83	55.33
	Female	67	44.67
Grade level	First grade	20	13.33
	Second grade	25	16.67
	Third grade	30	20.00
	Fourth grade	30	20.00
	Fifth grade	25	16.67
	Sixth grade	20	13.33
Teaching qualifications	Novice teacher	5	33.33
	Experienced teachers	5	33.33
	Expert teachers	5	33.33

3.2 Study of examples of lessons

The teaching content of the observed lesson examples is shown in Table 2. For the 15 elementary school teachers identified, two lessons conducted by each teacher were selected as observation cases, respectively the first and the last lesson of the teaching practice, to facilitate before-and-after comparisons. In order to avoid the influence of teaching content factors on the verbal interaction between teachers and students in classroom teaching, and to avoid the situation that the number of lessons with different teaching content varies too much and makes the observation results biased, when determining the observation examples, we paid attention to the principle of balancing the number of lessons with different teaching content as much as possible, and the final 30 lessons observed can be divided into X1~X5 categories according to the content of the teaching.

Table 2: Statistics of the teaching content of the observation lesson

Teaching content	Number of examples	Percentage/%
X1	6	20.00
X2	6	20.00
X3	6	20.00
X4	6	20.00
X5	6	20.00

3.3 Study design

The teaching practice period lasted from the beginning of March 2025 to the end of June 2025, a total of four months. In this paper, 30 lessons carried out by 15 elementary school teachers in City A were observed, and the observed lessons were videotaped. The level of practical skills of the study students was tested before and after the beginning of the teaching practice.

In the classroom observation session, this paper adopts the Design and Development Classroom Speech Subject Recognition Technology to realize intelligent observation, which mainly observes the teacher's speech characteristics and special speech, the student's speech characteristics and special speech, the emotional atmosphere of classroom teaching, and the special events occurring in the teaching process. The recording of the coding of various types

of teacher-student verbal interaction behaviors was conducted at the end of the classroom observation, based on the playback of the classroom teaching video.

In order to ensure the accuracy and validity of the coding of classroom observation records, professional teachers were asked to act as classroom observers of the recorded lessons in this paper. Before the professional teachers observed the lessons as observers, they were trained in the Flanders Interaction Analysis System to ensure that they could understand and familiarize themselves with the content and judgment criteria referred to in codes 1-14, and that they were able to quickly and accurately make judgments and record the types of verbal behaviors of the teachers and the students during the classroom observations. After the professional teachers had completed the observations, a comparison was made between the codes recorded by the system and those recorded by the professional teachers, and the comparison results showed that the agreement rate was 92.47%, confirming that the results recorded by the systematic observation had a high degree of credibility.

The validity of classroom observation is mainly determined by the observation tool used, and the classroom observation tool used in this study is the iFIAS system, which, as one of the classroom observation tools widely used in the field of educational research, has been proven to have good validity in practice, and is capable of recording and assessing teacher-student verbal interaction behaviors in classroom teaching in a more objective and accurate way.

4 Analysis of the impact of interactive classroom models on the development of students' thinking

4.1 Classroom Speech Subject Recognition

In this paper, a classroom speech subject recognition model is used for active speech detection, and after suppressing the non-speech parts, the beginning and end times of each audio segment are recorded and stored as text data. After detecting and labeling the speech segments in the audio stream, it is necessary to distinguish the speakers contained in them, i.e., speaker change detection. A sliding window is used for speaker change detection for each audio clip, and the distance between the sliding windows is calculated using the Bayesian information criterion, which is less than a threshold value to recognize the same speaker, and vice versa to mark it as a new audio clip.

After detecting the speakers in different segments, in order to analyze all the speeches of a particular speaker in the classroom, we need to cluster the segments of the same speaker together, i.e., perform speaker clustering. A research course was selected as an example for recognition and some of the speaker clustering results are shown in Figure 1. Six speaking audio segments are detected in this audio clip, which are labeled as audio segments 1~6. The BIC distance between each audio segment is computed in turn, and the audio segments are clustered and labeled as speaker 1 (0~119s), speaker 2 (119~277s), and speaker 3 (277~500s).

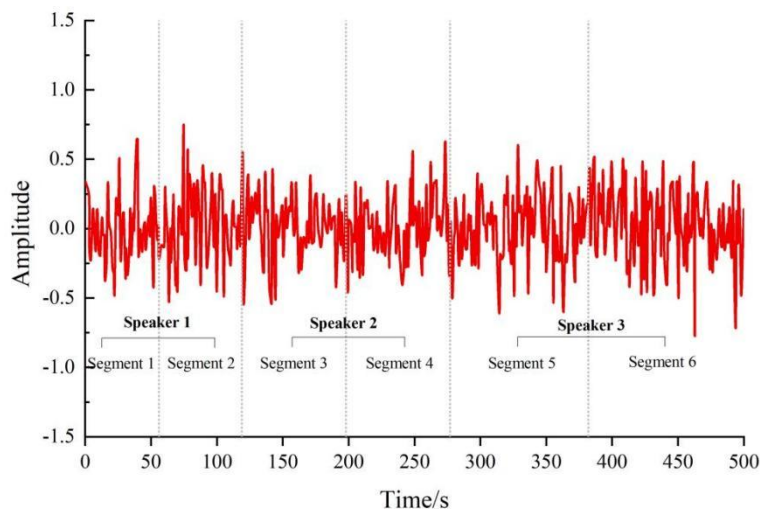


Figure 1: Clustering results of some speakers

The gender of the speech is further recognized and the results are shown in Figure 2. It can be seen that the teacher in this research course is female, student 1 is male and student 2 is female.

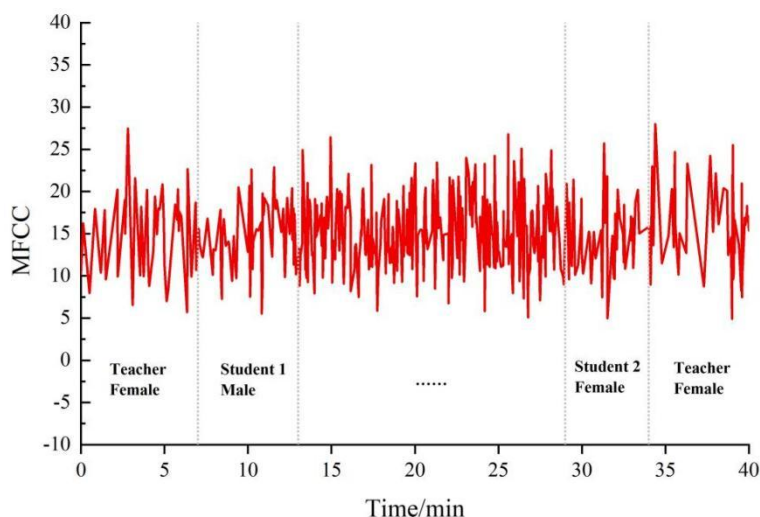


Figure 2: Speech gender recognition results

4.2 Analysis of classroom interaction

4.2.1 Matrix analysis

Classroom teacher-student behaviors were categorized using a matrix of 14 categories, with some cells in the matrix representing a particular teacher-student interaction. The analysis matrix is a cross-symmetrical chart that consists of cross-combinations of rows and columns (divided into 14 rows and 14 columns in this study). The sample classroom 1 and classroom 2 of the same teacher were selected for analysis and the results of their matrix analysis are shown in Tables 3 and 4, respectively. Based on the two factors of positive influence (coded 1 to 3) and negative influence (coded 6 to 7), the positive integration compartment and the negative integration compartment can be divided. In classroom 1, the total number of times in the positive integration compartment is 21, which indicates that the teacher interacts with the students more often in the classroom by encouraging and complimenting them. In area F

defective grids (coded 6 to 7), the larger the number indicates a greater disconnection between teachers and students. As can be seen from the above table, the number of defective cells totaled 12, which indicates a more harmonious relationship between teachers and students. Whereas, the presence of 0 times (7,7) coding indicates that there are no moments when the teacher needs to criticize or assert the authority of the teacher. Whereas the steady state zone, the grid where the diagonal line is located, the largest number, 98 times, fell in the steady state zone (5,5), which represents teacher-led classroom instruction, and there were 77 times in (10,10), which was in the second place, and this coding represents student discussion, which indicates that the students were more active and motivated to learn in that class. The teacher made lesson plan adjustments based on the results of the classroom interaction analysis, and in Classroom 2, the number of times in the active integration zone totaled 27, and the number of times in the defective grid totaled 6. Falling in the homeostatic zone (10, 10) with the largest number of 105, it can be seen that classroom instructional efficacy was effectively improved.

Table 3: Results of matrix analysis for Class 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1	3	0	0	1	1	0	0	0	0	0	0	0	0	0	5
2	1	2	6	3	0	0	0	2	0	0	0	0	0	0	14
3	0	0	9	1	0	0	0	0	1	0	0	0	0	0	11
4	0	0	0	26	0	0	0	5	31	2	0	0	0	1	65
5	0	0	0	6	98	3	0	0	17	2	0	5	2	9	142
6	2	0	0	2	0	12	0	2	2	1	0	0	3	0	24
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8	0	3	3	0	2	0	0	51	0	0	0	0	0	0	59
9	2	8	2	13	9	2	0	0	76	0	0	2	0	9	123
10	0	0	0	2	0	0	0	2	1	77	0	0	0	0	82
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	5	2	0	0	0	0	0	16	0	2	25
13	0	0	0	2	1	1	0	0	0	0	0	0	34	0	38
14	0	0	0	7	5	2	0	0	1	3	0	2	0	32	52
Total	9	13	20	63	121	22	0	62	129	85	0	25	39	53	641

Table 4: Results of matrix analysis for Class 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1	2	0	0	3	0	0	1	0	0	0	0	0	0	0	6
2	1	4	6	1	0	0	1	0	0	0	0	0	0	0	13
3	0	0	14	0	0	0	0	0	0	0	0	0	1	0	15
4	0	0	0	22	0	0	0	5	31	4	0	0	0	2	64
5	0	0	0	5	67	2	0	0	17	1	0	3	0	7	102
6	1	0	0	1	0	6	0	2	2	1	0	0	2	0	15
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	2	1	0	3	0	0	61	0	0	0	0	0	0	67
9	1	4	6	13	5	1	0	0	68	0	0	1	0	7	106
10	0	0	0	1	0	0	0	0	2	105	0	0	0	0	108
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	4	0	0	0	0	0	0	21	1	3	29
13	0	0	0	0	2	1	0	0	0	0	0	0	29	0	32
14	1	0	0	8	3	4	0	0	0	2	0	1	0	19	38
Total	6	10	27	54	84	14	2	68	120	113	0	26	33	38	575

4.2.2 Behavioral statistics results

An attempt was made to present the clip clearly in Excel, and the results of the visualization of the teaching clip in Classroom 1 and Classroom 2 are shown in Figure 3. The long period of “10-14-5” in Classroom 1 shows that the teacher promotes student discussion and hands-on work, and then gives comments on the students' results. In Classroom 2, the frequent occurrence of “8-4-12-4-12-4-12-4-12-4-8” shows that the teacher increased the frequency of classroom questions based on the results of the analysis of classroom interactions, encouraged students to think in questions and answers, found students' problems in time, and mobilized the activity of thinking.

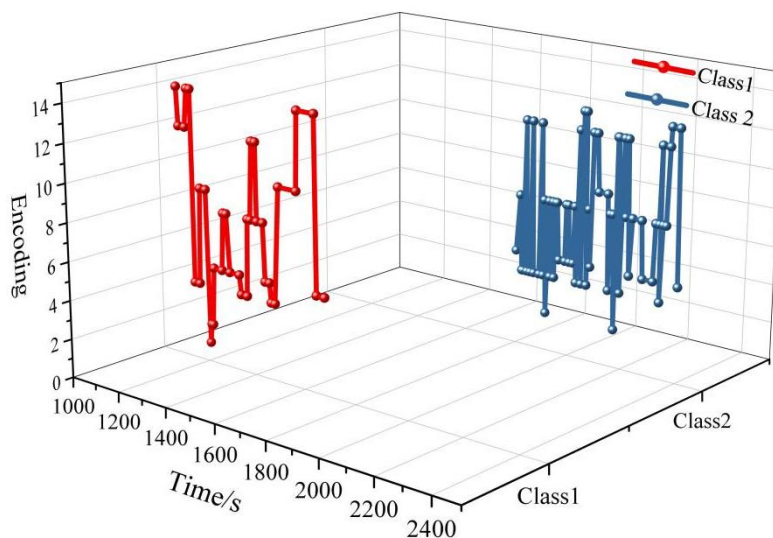


Figure 3: Visualized results of teaching segments in Class 1 and Class 2

4.3 Analysis of application results

4.3.1 Impact on thinking skills

The last lesson of five teachers' teaching practice was selected for analysis, numbered C1~C5. The students' thinking levels were refined in tiers, and the results of the assessment of students' thinking levels are shown in Table 5. It can be seen that each lesson contains 2~3 higher-order thinking skills, and the percentage of students' high-level level is above 50%. With the empowerment of technology, teachers are able to analyze the classroom interaction behavior more clearly and promote the formation of an interactive classroom with teachers and students as the “dual center”. In other words, teachers use their words and actions to guide students to participate in classroom teaching, which helps to make the classroom teaching process more diversified, enriched and optimized, and in turn improves students' thinking skills.

Table 5: Evaluation results of students' thinking level

	Higher order thinking skills	Percentage/%	
C1	Problem-solving ability	Low	4.02
		Medium	38.91
		High	57.07
	Critical thinking ability	Low	2.45
		Medium	23.78
		High	73.77
C2	Problem-solving ability	Low	5.14
		Medium	26.82
		High	68.04
	Creative thinking ability	Low	7.23
		Medium	30.15
		High	62.62
	Judgment and decision-making ability	Low	4.55
		Medium	34.12
		High	61.33
C3	Critical thinking ability	Low	6.48
		Medium	33.19
		High	60.33
	Creative thinking ability	Low	5.14
		Medium	28.95
		High	65.91
C4	Problem-solving ability	Low	4.23
		Medium	43.15
		High	52.62
	Creative thinking ability	Low	3.28
		Medium	29.65
		High	67.07
C5	Critical thinking ability	Low	7.02
		Medium	38.15
		High	54.83
	Creative thinking ability	Low	4.58
		Medium	42.33
		High	53.09
	Judgment and decision-making ability	Low	2.16
		Medium	37.29
		High	60.55

4.3.2 Learning outcomes

The analysis of students' practical ability mainly focuses on three aspects: their mastery of knowledge, practical ability and innovative ability. The five-level Likert scale is used for assessment, namely "very consistent", "basically consistent", "average", "basically inconsistent" and "completely inconsistent". The answer sheets are distributed and collected through the Wenjuanxing platform. In data analysis, the options "fully comply" and "comply" are identified as having a basic grasp of this ability, while the options "basically do not comply" and "completely do not comply" are identified as having a basic lack of mastery of this ability.

Students' knowledge mastery is divided into 3 dimensions (numbered A1~A3), students' practical ability is divided into 4 dimensions (numbered B1~B4), students' innovation ability is divided into 2 dimensions (C1~C2), namely, activity innovation ability and activity reflection ability, and pre- and post-tests are conducted. The comparison results are shown in Figure 4. The greatest change in students' practical ability is found in the ability to find problems, and the proportion of mastery grows from 32% to 90%, which can be seen to be related to the rise of students' active thinking. In addition, the percentage of students' mastery of each competency in the posttest increased, reaching more than 75%.

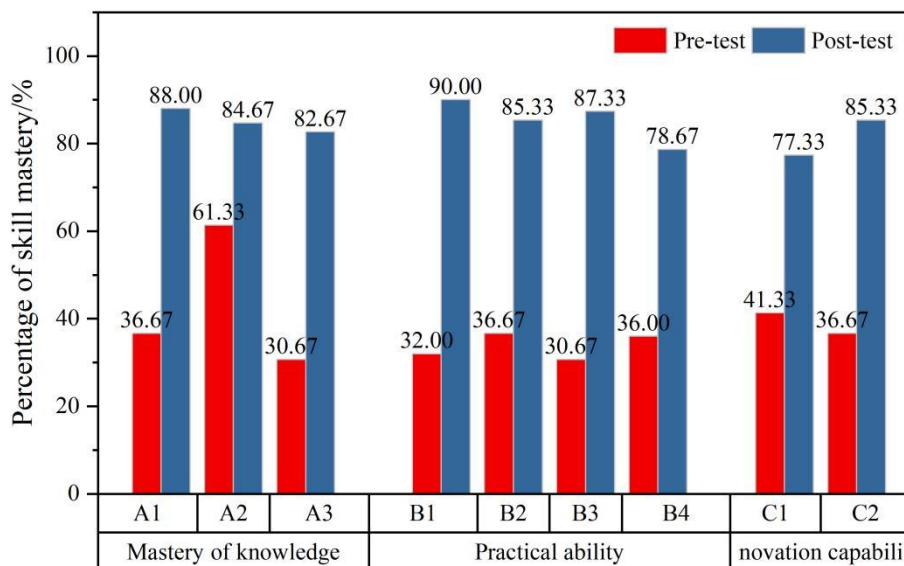


Figure 4: Comparison results of Pre-test and Post-test

5 Conclusion

In this paper, we designed a classroom interaction analysis method combining neural network and Flanders system to carry out a 4-month-long teaching practice to investigate the effect of the proposed classroom interaction model on the development of students' thinking.

In Classroom 1, the number of times in the positive integration zone totaled 21, and the number of defective grids totaled 12, with 77 times in (10, 10), which is in the second place. In Classroom 2 the sum of counts in the positive integration zone was 27 and the counts of defective frames totaled 6. The largest number of counts fell in the homeostatic zone (10, 10) with 105 counts. In Classroom 1, there was a long period of “10-14-5”, while in Classroom 2, there was a frequent period of “8-4-12-4-12-4-12-4-12-4-8”. In other words, after the teacher adopted the designed classroom interaction model, students' active learning increased.

In the practice post-test, each class included 2-3 higher-order thinking skills, and the percentage of students at the higher level was above 50%. The students' ability to identify problems in the practice competencies grew to 90%, indicating that the technology-enabled classroom interaction strategy was effective in promoting students' thinking development.

About the Author

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