Research on the Framework of Classroom Interaction Behavior Analysis Based on Artificial Intelligence

Yuting Huang and Chongwen Wang
Beijing Institute of Technology, Beijing, China
Email: audrey_huang98@163.com, wcwzzw@bit.edu.cn

***Abstract*—Classroom teaching is a system of social activities. As the subject of the activities, teachers, and students are engaged in various interactions, which are called interactions in classroom teaching. Classroom interaction is one of the important factors affecting the teaching effect. It shows in every part of the classroom teaching process and forms a good interaction between each other around the realization of education and teaching objectives. Under the background of educational informatization, using information technology to observe and analyze classroom teaching behavior can promote the development of teaching activities, improve the efficiency of classroom evaluation and teaching quality. This paper starts with the interaction subject and the interactive media to carry out the analysis framework of classroom interaction behavior. In classroom teaching, there are two main bodies directly involved, namely teachers and students. The medium of interaction between subjects is audio or action. Artificial intelligence technology is combined with classroom interaction analysis to classify classroom interaction types by using audio and video information in classroom teaching. The basic interactive classification of classroom teaching can be obtained by combining the two types of subjects with different audio or action.**

***Index Terms*—classroom interaction, Delphi method, speaker recognition, target detection**

I. Introduction

A. Research Background

Classroom teaching is an interactive process between teaching activities of teachers and learning activities of students based on teaching materials [1]. At present, China's higher education is in the stage of rapid development, teaching quality is the foundation of school development, and teaching quality evaluation is the standard to measure teaching quality, give full play to the function of teaching evaluation is conducive to improve teaching quality, help students grow and all-round development [2]. Classroom interaction runs through the whole process of classroom teaching, which forms a benign interaction between each other around the realization of education and teaching objectives. Classroom teaching is a system of social activities, as the subject of the activities of teachers and students are bound to carry out a variety of interaction and interaction, we call these interactions and interactions in classroom teaching. Interaction in classroom teaching is an important factor affecting the teaching effect. For example, the way of interaction between teachers and students has a direct impact on classroom atmosphere, feedback in class and students' participation in class. At the same time, interaction in classroom teaching is also the basic way of individual socialization of students. In this social environment, students learn cultural knowledge, value goals and social norms through interaction and interaction with others. Therefore, we should pay attention to the study of classroom teaching interaction behavior, scientific guidance, make it play to optimize the quality of teaching, promote the development of students [3].

The reform of higher education in the information age requires universities to carry out intelligent classroom teaching mode and improve the development level of higher education connotation. With the arrival of the information age of teaching philosophy and teaching technology changing with each passing day, the intelligent education process data are collected by intelligent devices and analyzed and processed by means of artificial intelligence, from which students' learning characteristics and learning performance are found.

B. Research Status Analysis

1) Weakly analysis

Classroom interaction is manifested through a series of interactive behaviors between teachers and students. At present, most of the researches on interactive behavior in classroom teaching focus on the category of verbal interaction behavior. The more classic is the Flanders interactive analysis coding system [4]. The details are shown in Table I.

As can be seen from the table of Flanders coding system, most interactive analysis systems at present focus on speech, and take the semantic and voice of speech as the main analysis object. Kangning Wu and other scholars pointed out that the interaction between teachers and students is a kind of differentiated interaction. When teachers interact with students, they will be different due to the gender, performance and position of students, which is reflected in the teacher's evaluation, criticism and praise, emotional attitude and so on [8]. Therefore,

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semantic information as the classification standard in the current research methods of classroom interaction behavior has the problem of single analysis content and great influence of subjective factors.

TABLE I. INTERACTIVE ANALYSIS CODING SYSTEM IN FLANDERS

Teachers' speech	Immediate effects	1	inclusive
		2	Appreciation and encouragement
		3	Identify and adopt the student situation
		4	Ask questions
	Indirect effects	5	teach
		6	instructions
		7	Criticism and authority maintenance
Student speech		8	Student's Speech (response)
		9	Student presentations (leading)
Silence and chaos		10	No valid speech

2) Outdated analysis tools

Traditional classroom interaction analysis is mainly carried out by human resources. Most of the evaluators analyze the classroom through offline lectures and online questionnaires. These data are often analyzed by manual operation of Office software, and lack of data accumulation, storage and vertical and horizontal comparison and analysis [8]. In the process of teaching evaluation, although the evaluators have rich experience, the evaluation is limited to a specific time, lack of continuity, and cannot objectively reflect the dynamic process and real level of teachers' teaching development [7].

II. CONSTRUCTION OF CLASSROOM INTERACTION ANALYSIS FRAMEWORK BASED ON ARTIFICIAL INTELLIGENCE

Based on artificial intelligence, this paper analyzes classroom interaction behaviors through classroom teaching videos collected by intelligent devices According to the constructed classroom interaction analysis framework, all interaction categories included in a class are obtained. his information-based classification mode not only makes the evaluation results more real and accurate, but also greatly improves the feedback function and real-time performance of the evaluation results, which really realizes the purpose and original intention of teaching evaluation and plays a role in improving the teaching quality of teachers and students' learning quality.

In order to make full use of classroom teaching video information, this paper comprehensively observes the interactive behavior in classroom teaching from multiple dimensions and perspectives Combining the traditional perspective of classroom interaction classification with the requirements of classroom teaching evaluation under the guidance of efficient classroom, the observation dimension and evaluation dimension of classroom interaction classification are proposed. The combination of these two dimensions constructs the classroom teaching behavior analysis framework based on artificial intelligence.

A. Observation Dimensions of Class Interaction Classification

Interaction usually refers to the mutual influence and interaction between two subjects with the help of certain media (language or body). Therefore, classroom interaction refers to the mutual influence and interaction between teachers and students and between students with the help of words, body, gestures and teaching materials in the classroom teaching situation, whose content includes knowledge, emotion, attitude and so on. Classroom interactions can be classified from many different perspectives. Kangning Wu classifies according to the subjects, and the types obtained after the combination of various interactive subjects are relatively comprehensive [8]. According to the purpose and content of classroom interaction, Nanrong Cai divides knowledge interaction, emotion interaction and action interaction.

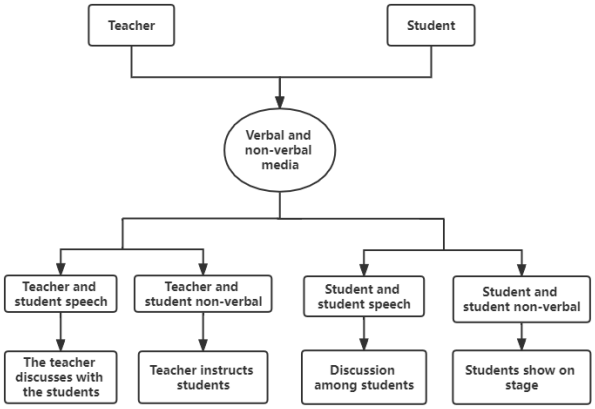

Figure 1. Observation dimensions of classroom interaction classification.

In this paper, interactive subjects and media constitute the classification observation dimension. In classroom teaching, there are only two main bodies directly involved in social activities, namely teachers and students. The interaction between teachers and students can be said to be the most common interaction. Most of the time and content of classroom teaching are reflected in the interaction between teachers and students. This interaction mainly occurs in the organization of teaching, classroom telling, classroom questioning, classroom evaluation[9]. Student to student interaction is commonly seen in class discussions, with neighboring students discussing the content of class and homework, or a student demonstrating his or her ideas in front of the whole class. Classroom interaction media can be divided into two categories: verbal interaction and non-verbal interaction. Speech interaction is a basic medium. Teachers' speech acts are used not only to communicate with students about curriculum and learning requirements, but also to communicate with students about emotions, organize relationships and various activities [10]. The

general performance in the classroom is the interaction between the teacher and the student. Nonverbal behavior is another kind of media, usually nonverbal interaction through body or gesture, or nonverbal interaction through various materials. The general performance of vision in class is that students go on stage to demonstrate to other subjects and teachers guide students in class.

The combination of interaction subjects and the two types of media constitutes the observation dimension of classroom interaction classification in this paper, as shown in Fig. 1.

B. Evaluation Dimensions of Class Interaction Classification

The observation dimension of class interaction classification based on artificial intelligence is mainly for the intelligent collection of early data in the actual analysis process, and then the evaluation dimension of the analysis data needs to be constructed. The evaluation dimension of classroom interaction classification in this paper mainly starts from the objectives of classroom teaching and the evaluation criteria of intelligent classroom to ensure the scientific and comprehensive analysis framework of classroom interaction based on artificial intelligence [11].

Classroom effectiveness refers to the degree of achieving the goal of classroom teaching activities and the teaching ability of teachers to ensure the realization of the goal. The classroom objectives under the guidance of efficient classroom will focus on the two levels of teaching quality and teaching efficiency, and test whether the realization of teaching objectives is effective or efficient[12]. In conclusion, it can be found that efficient classroom requires us to come up with indicators of teacher-student interaction rate at the level of classroom interaction, which can be analyzed through behavioral data collected in class. We can take the frequency of interaction and the number of participants as quantitative indicators, corresponding to the evaluation standards at the quantitative level in classroom scenes.

TABLE II. ANALYSIS FRAMEWORK OF CLASSROOM INTERACTION BEHAVIOR BASED ON ARTIFICIAL INTELLIGENCE

The main body	medium	Subject and medium	frequency	Participant
Teacher and students	verbal and nonverbal	The teacher discusses with the students	Brief discussion between teachers and individual students (TSTT...)	
			Complex discussions between individual teachers and students (TSTST...)	
			Brief discussion between teachers and student groups (TSsTT...)	
			Complex discussions between teachers and student groups (TSsTSsT...)	
		Students have a discussion with students	Student to student discussion (SS...)	
		Teacher instructs students	The teacher instructed the students under the platform	
		Students show on stage	Students show on stage	

With the help of evaluation dimension, this paper subdivides the class interaction classification on the quantitative level. Among them, the number of participants corresponds to the number of interaction subjects, namely, the distinction between individual teachers (represented by T), individual students (represented by S) and student groups (represented by Ss). Frequency refers to the number of interactions between the two sides of the subject. In actual classroom scenes, interaction frequency can only be divided into one and multiple times, so the threshold value of frequency is only defined as 1. Meanwhile, in order to facilitate the construction of subsequent analysis framework, the interaction frequency equal to 1 is set as "simple" interaction, and the interaction frequency greater than 1 is set as "complex" interaction. Table II shows the final analysis framework.

C. Determination of the Classroom Interaction Analysis Framework Based on Artificial Intelligence

In order to verify the rationality of the framework, experienced practitioners and experts in the field of classroom teaching analysis are required to judge the rationality of the observation dimension and evaluation dimension. In this paper, Delphi method is adopted to consult the observation dimension and evaluation dimension of the analysis framework by organizing expert opinion consultation group[13]. This paper plans to select 15 experts from three directions, who are respectively engaged in artificial intelligence and education issues, informatization teaching field and teachers with rich teaching experience. They have an in-depth understanding of the classroom scene and can put forward opinions on the research framework from their perspective, which is conducive to the formulation of a research framework with high feasibility and wide applicability[14].

1) First round of delphi consultation

The purpose of the first round of expert survey is to solicit experts' opinions on the revision of the classification of observation dimensions and evaluation dimensions proposed in this paper, and to score the importance of indicators to ensure the rationality of the results of the framework system and each indicator. The importance of the questionnaire was set on a scale from very unimportant to very important (1-5 points). Table Ⅲ lists the questionnaire. The opinion consultation questionnaire was sent to the consultation expert group, which was scored by the group members. At the same

time, in order to prevent omissions in the framework index system constructed for the first time, the open opinion consultation method was set in the questionnaire.

TABLE III. THE FIRST CONSULTATION QUESTIONNAIRE

indicator	Importance rating				
	Very unimportant (1)	Not important (2)	Not sure (3)	important (4)	Very important (5)
The main body					
medium					
frequency					
Participate					
others					

In the first round, 15 questionnaires were issued and recovered, with a recovery rate of 100%. The analysis of the questionnaire was mainly carried out through standard data statistics, and the mean, median and standard deviation of each index were calculated. The mean value represents the degree of experts' recognition of the index and the importance of the index, the median represents the degree of experts' approval of the index and the concentration of their opinions, and the standard deviation can present the dispersion of experts' opinions[14]. The greater the standard deviation, the greater the dispersion of expert opinions, and vice versa. In addition, coefficient of variation (standard deviation/mean) is often used as an indicator in Delphi research method to test the degree of unity of experts' opinions on all indicators, which represents the credibility of the results[6]. Combined with the survey results of the opinion consultation questionnaire, the main statistics calculated in this paper are: the mean and median to measure the average state, and the standard deviation and coefficient of variation to measure the fluctuation change state. The results are shown in Table IV below.

TABLE IV. RESULTS OF THE FIRST CONSULTATION QUESTIONNAIRE

indicator	Descriptive statistical item			
	The average	The median	The standard deviation	Coefficient of variation
The main body	4.70	5.00	0.618	0.131
medium	4.87	5.00	0.363	0.075
frequency	4.53	4.00	0.961	0.212
Participate	4.80	5.00	0.426	0.089

It can be seen from the statistical analysis in the above table that: (1) average and median are commonly used to indicate the experts' suggestions on the importance of indicator items. The four indicators of the two statistical items are all above 4, indicating that the experts agree on the importance of these four indicators. (2) Standard deviation and coefficient of variation are used to indicate the degree of consistency of expert opinions. Generally, those with standard deviation greater than 1 or coefficient of variation greater than 0.3 are considered to have low degree of expert unity. According to the results, the performance results of the indicators proposed in this paper meet the screening criteria in these two statistical items. Based on the evaluation results of experts and the feedback of modification opinions, we can know that the observation dimension and evaluation dimension proposed in this paper are relatively reasonable.

2) Second round of delphi consultation

In order to further supplement and improve the classroom interaction analysis framework of this paper, the second round of Delphi consultation was carried out. The purpose of the second round of expert surveys was to solicit experts' opinions on modifications to the interaction categories proposed in this paper and to rate the importance of each category. Table V lists the questionnaire.

TABLE V. SECOND OPINION CONSULTATION QUESTIONNAIRE

Class interaction classification	Importance rating				
	Very unimportant (1)	Not important (2)	Not sure (3)	important (4)	Very important (5)
Brief discussion between teachers and individual students (TSTT...)					
Complex discussions between individual teachers and students (TSTST...)					
Brief discussion between teachers and student groups (TSsTT...)					
Complex discussions between teachers and student groups (TSsTSsT...)					
Student to student discussion (SS...)					
The teacher instructed the students under the platform					
Students show on stage					
others					

A total of 15 questionnaires were distributed in the second round and 14 were recovered, with a recovery rate of 93.3%. Combined with the analysis of the results of the first round of opinion consultation, the average and median were still selected to analyze the average situation, as well as standard deviation and coefficient of variation to measure the fluctuation. Table VI shows the statistical results.

According to the second-round evaluation of Delphi experts and the statistical analysis of all indicators in the

table above, it can be seen that among the 7 indicators, the index item "complex discussion between teachers and students" has a low average value, a large standard deviation and a large coefficient of variation. Based on the suggestions of the expert group, the classification needs to be improved. "Complex discussion between teachers and student groups" should include a variety of situations: TSsTSsT..., TSsTST..., TSTSsT.... Finally, according to the results of the two rounds of Delphi consultation, the final analysis framework of classroom interaction behavior based on artificial intelligence can be obtained (to facilitate the presentation of the results, each interaction category is replaced by a label), as shown in Table VII.

TABLE VI. RESULTS OF THE SECOND OPINION CONSULTATION QUESTIONNAIRE

Class interaction classification	Descriptive statistical item			
	The average	The median	The standard deviation	Coefficient of variation
Brief discussion between teachers and individual students (TSTT...)	4.86	5.00	0.376	0.077
Complex discussions between individual teachers and students (TSTST...)	4.93	5.00	0.277	0.056
Brief discussion between teachers and student groups (TSsTT...)	4.86	5.00	0.376	0.077
Complex discussions between teachers and student groups (TSsTSsT...)	4.29	4.00	1.050	0.245
Student to student discussion (SS...)	4.93	5.00	0.277	0.056
The teacher instructed the students under the platform	4.79	5.00	0.439	0.092
Students show on stage	4.71	5.00	0.630	0.134
others				

TABLE VII. ANALYSIS FRAMEWORK OF CLASSROOM INTERACTION BASED ON ARTIFICIAL INTELLIGENCE

The main body	medium	Subject and medium	Frequency	Participate
Teacher and students	verbal and nonverbal	The teacher discusses with the students	Brief discussion between teachers and individual students (TSTT...)(a)	
			Complex discussions between individual teachers and students (TSTST...)(b)	
				Brief discussion between teachers and student groups (TSsTT...) (c)
				Complex discussion between teacher and student groups (TSsTSsT... TSsTST... TSTSsT,...) (d)
		Students have a discussion with students		Student to student discussion (SS...)(e)
		Teacher instructs students		The teacher instructs the students under the platform (f)
		Students show on stage		Students present (g)

III. APPLICATION OF CLASSROOM INTERACTION ANALYSIS FRAMEWORK BASED ON ARTIFICIAL INTELLIGENCE

On the basis of the above, in order to better test the operability of the ai-based classroom interaction analysis framework, the analysis framework is applied to the real classroom scenes. Firstly, the analysis process based on artificial intelligence in real classroom scenarios is sorted out based on the analysis framework proposed in this paper, and then the process of intelligent analysis of classroom interaction behavior with the help of artificial intelligence technology is clarified.

A. Analysis Process of Classroom Interaction Based on Artificial Intelligence

The analysis framework of classroom interaction based on artificial intelligence divides classroom interaction into seven categories according to the observation and evaluation dimensions. Seven of them can be roughly divided into verbal interaction and non-verbal interaction. Combined with the collected classroom video information, the process of using artificial intelligence to analyze classroom interaction behavior is shown in Fig. 2.

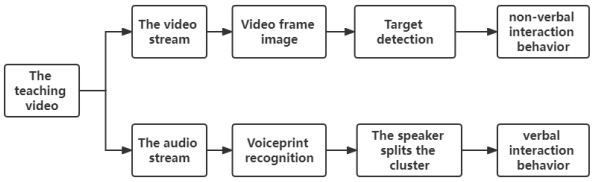

Figure 2. Flow chart of classroom interaction behavior analysis based on artificial intelligence.

According to the analysis of the flow chart, we need to process the collected classroom teaching videos from two dimensions. For the speech stream in video, voice pattern recognition and speaker segmentation and clustering are used to obtain the time series data of speaker change. Then, according to the time series data and the definition of interaction in the analysis framework, the classroom language interaction behavior is obtained. According to the image information in the video, we intercept the image data according to the frame, and obtain the

classroom non-verbal interaction behavior according to the human pose estimation and face recognition technology.

Through the data processing and analysis process, the corresponding data processing and the classroom interaction analysis framework based on artificial intelligence technology are combined to obtain the classroom interaction behaviors contained in each class, thus helping to comprehensively analyze the whole class. Finally, the generated data can be visually presented to managers, teachers or students and other relevant groups to help form health education ecology.

B. Experiment and Result Analysis

This paper only takes the speech interaction behavior detection as an example and elaborates the specific application of the analysis framework in combination with the preset classroom teaching behavior analysis process to ensure the feasibility and operability of the analysis framework.

1) Experimental data

The test data set of this experiment is the audio data recorded in the open class, and 10 pieces of audio are randomly selected from the class data set as the material of this experiment. The research object of this experiment is the teacher and student in the audio data. Combined with the observation and evaluation dimensions of the analysis framework, the experiment needs to detect all the language interactions contained in the classroom. The experimental data are shown in Fig. 3.

A0001_1.wav	20 422
A0002_9.wav	21 295
A5769_4.wav	4 010
A6046_7.wav	6 074
A6135_3.wav	4 377
A6755_1.wav	29 153
A7149_1.wav	7 625
A7215_3.wav	20 644
A7217_1.wav	20 466
A7218_4.wav	26 678

Figure 3. Experimental data graph.

2) Experimental process and results

The overall speech interaction processing process is as follows: (1) using VAD speech detection framework, the audio frame is divided into two categories: speech and non-speech. (2) D-vector of fixed length of each audio is obtained by RNN model, and the embedding code of each speaker is the mean of all audio embedding vectors. (3) Speaker conversion detection adopts the method based on window classification, and the data is solved as a standard sequence labeling problem. The label of transition point is 1, and the label of non-transition point is 0.At the same time, Focal Loss function was used to alleviate category imbalance. (4) In order to make full use of speaker labels, the supervised clustering model and speaker embedding are modeled by parameter sharing recursive neural network, and different RNN states interwoven in the time domain are used to distinguish different speakers. Finally, the standard stochastic gradient descent algorithm is used to train the classification model [16]. Fig. 4 shows the algorithm flow chart.

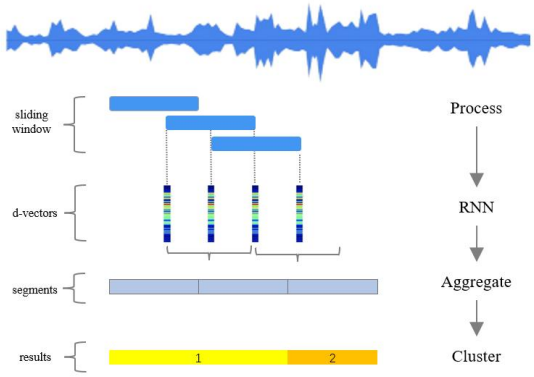

Figure 4. Algorithm flow chart.

Input audio into the network designed above, time sequence data with labels will be obtained, as shown in Fig. 5 for A0001_1 visualization results.

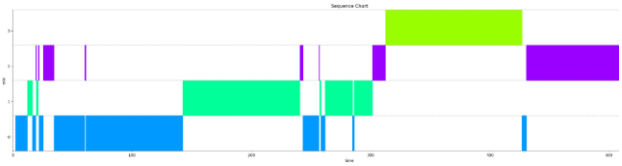

Figure 5. Labeled time series data.

All types of interactions included in the class are then examined based on the resulting temporal data. The specific process is as follows: (1) firstly, the data obtained are preprocessed. The speech duration less than 50ms is set as interference noise and removed from the result data. (2) The active voice duration of all roles was counted, and the role with the longest duration was marked as teacher. (3) A sliding window with a length of 5000ms and an overlap rate of 50% is used to detect whether the interaction type set above is included, and finally the interaction results are output. Table VIII shows the output.

TABLE VIII. THE EXPERIMENTAL RESULTS

audio	The interaction results
A0001_1	(a)->(d)->(a)->(a)->(d)->(a)->(e)->(e)->(a)
A0002_9	(a)->(a)->(b)->(a)->(a)->(d)->(e)->(e)->(e)->(a)
A5769_4	(a)->(a)->(d)->(a)->(a)
A6046_7	(a) ->(a)->(b)->(e)->(a)->(a)
A6135_3	(a) ->(a)->(a)->(c)->(e)->(a)
A6755_1	(a)->(b)->(a)->(b)->(e)->(e)->(e)->(e)->(a)->(d)
A7149_1	(a)->(a) ->(a)->(c)->(a)->(a)
A7215_3	(a)->(a)->(a)->(b)->(b)->(a)->(d)->(a)->(a)->(a)
A7217_1	(a)->(b)->(b)->(a)->(a)->(a)->(a)->(a)->(b)->(d)->(d)
A7218_4	(a)->(d)->(d)->(a)->(a)->(a)->(a)->(c)->(c)->(a)

C. Advantages of Ai-Based Classroom Interaction Analysis Framework

1) The analysis is rich

The framework of classroom interaction analysis based on artificial intelligence proposed in this paper is different from the traditional analysis method, which is mainly semantic. The framework of classroom interaction

analysis composed of observation dimension and evaluation dimension is proposed. Class interaction types are divided from the perspective of the subject, and both the subject's speech behavior and non-speech behavior are included in the analysis framework. Accurate and comprehensive classroom data are collected through the cameras installed in the classroom, and abundant information is obtained by using artificial intelligence technology, which greatly enriches the analysis content of classroom interaction behavior in this paper. At the same time, this paper puts forward the evaluation dimension according to the standard of efficient classroom, which measures the classroom interaction behavior from the two perspectives of frequency and attendance, and further details the classroom interaction behavior.

2) Analysis tool intellectualization

Relying on artificial intelligence technology, the collected classroom images and sound signals are processed, and target detection, speech recognition and other technologies are used to automatically calculate and analyze the collected information. It can automatically analyze the interaction behaviors in classroom teaching and feedback the analysis results in time. After class, teachers can analyze the teaching situation according to the analysis results of artificial intelligence technology feedback, adjust the teaching method dynamically in time, and realize the effect of solving problems in time. The informatization of analysis tools not only makes the analysis results more real and accurate, but also greatly improves the feedback function of classroom interaction analysis, which really realizes the purpose and original intention of classroom interaction analysis and plays a role in improving the teaching quality of teachers and the learning quality of students.

IV. Conclusion

Combining theoretical research and practical research, this paper provides a new perspective for the existing framework of classroom interaction analysis. From the perspective of artificial intelligence technology driving teaching, this paper aims to construct a scientific framework of classroom interaction analysis. Artificial intelligence technology is used to avoid the repetitive and inefficient work of human analysis and effectively improve the quality of classroom interaction behavior analysis.

However, due to the limited classroom teaching resources, the collection of students' voices is not clear enough to deeply explore the characteristics of speech. In the future, classroom interaction can be further subdivided with the help of text features, so that the analysis dimension of classroom interaction can be expanded and a more diversified analysis framework can be obtained.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yuting Huang is mainly responsible for the determination of the framework and the realization of technical solutions; Chongwen Wang assisted in the search for experts and the development of the questionnaire.

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Yuting Huang was born in Wuhan, Hubei Province in 1998. From 2015 to 2019, She studied at Jiangnan University, Wuxi City, Jiangsu Province, majoring in computer science and technology. Since 2019, she has been studying for a master's degree at the School of Computer Science, Beijing Institute of Technology, Beijing. During this period, the research direction was object detection, especially to break through the difficulties of small target detection.

During her postgraduate studies, she was selected to participate in the laboratory Nature Fund project "Research on the Quality of Classroom Teaching Based on Artificial Intelligence". She is mainly responsible for the detection of students' heads and the detection of low head-up rates in classroom scenarios.

Chongwen Wang doctor, associate professor, School of Computer Science, Beijing Institute of Technology. In April 2003, he entered Beijing University of technology, mainly engaged in teaching and scientific research. His main research interests include computer vision, small target detection, digital media technology, etc. In 2008, he get Technology Olympics advanced collective of Ministry of science and technology.

In 2015, he won the third prize of science and technology of Beijing. In 2011 and 2009, he got Special award (the first place) of "Zhongke cup" software Innovation competition.