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Analysis and Improvement of Artificial Intelligence Classroom Teaching:The Collaborative Mechanism of Human in the Loop

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Abstract: Classroom teaching analysis is the basis for teaching improvement,and teaching improvement is the key to improving teaching quality.The two interact and form a loop of classroom teaching research.At present,there are difficulties in the field of artificial intelligence in classroom teaching research,such as unclear human-machine collaboration mechanisms,weak correlation between teaching analysis and improvement,and weak guidance for teaching practice applications.The study draws inspiration from the dual path learning and human in loop design optimization ideas of usage theory,and proposes a"teaching structure"as the focus of classroom teaching analysis and improvement of the loop.The loop is divided into high intervention and low intervention areas,and the collaborative mechanism of human intelligence and artificial intelligence in the loop is discussed.Research has found that constructing a TEST II classroom teaching analysis model and a 4A improvement model of"structural analysis,problem discovery,strategy improvement,and practical application"can form a human-machine collaborative classroom teaching analysis and improvement mechanism in the loop,providing feasible solutions for promoting the transformation of classroom teaching structure and improving the quality of classroom teaching.

Key words: Artificial intelligence; Classroom teaching analysis; Teaching improvement; Dual path learning; Man in the loop

1 Introduction

The classroom is the main battlefield of educational reform and the key environment for improving the quality of education and teaching.Treating classroom teaching analysis and improvement as a complete loop,supporting improvement through analysis,and optimizing analysis based on improvement has become a driving force for iterative updates in classroom teaching research. Traditional classroom teaching analysis and improvement mainly rely on on-site or video observation,interview questionnaires,and other analysis methods,with collective listening and expert feedback as the source of feedback and improvement.There are problems such as time-consuming and inefficient,strong subjectivity,delayed feedback,and difficulty in gathering group wisdom.With the rapid development of intelligent technology and the promulgation of a series of policies such as promoting the construction of teacher teams through artificial intelligence,classroom teaching research supported by artificial intelligence technology has ushered in a development opportunity and urgently requires in-depth exploration in theory and practice.

2 Key Issues in Artificial Intelligence Supporting Classroom Teaching Research

Artificial intelligence is a technical discipline that simulates,extends,and extends the theories,methods,techn ologies,and application systems of human intelligence.It includes technologies such as computer vision,natural language understanding,knowledge graph,and machine learning that simulate human intelligence.The use of artificial intelligence to assist classroom teaching research is an emerging interdisciplinary research direction.Below are several representative technologies to list.Computer vision can analyze classroom interaction,attention,and participation by identifying teacher-student behavior data,facial expression data,etc.For example,Watanabe and others use computer vision technology to analyze classroom videos,and use multi-layer neural networks to model teachers'blackboard writing and teaching behavior,as well as the interaction between students'note taking and listening behavior;SensorStar Laboratory and Paris Business School use computer vision to analyze students'classroom reactions,determine their attention,and measure their classroom participation by collecting smiles,frowns,and sounds,or analyzing eye movements and facial expressions during online learning. Natural language processing technology can provide good support for classroom teaching analysis and evaluation,especially for classroom speech analysis.For example,Ma Yuhui et al.proposed an automatic analysis method for classroom questioning based on deep learning,using convolutional neural networks and short-term memory networks to classify and analyze 9090 classroom teacher questioning texts from 80 classes.The overall accuracy in the dimensions of questioning content and questioning type is 85.17%and 87.84%,respectively.This method can basically replace manual analysis and achieve large-scale automatic analysis of classroom questioning discourse.Cao Yiming and others adopted machine learning to construct an artificial intelligence evaluation system for mathematics classroom dialogue in Education 2030,achieving large-scale classroom teaching analysis and comparison,as well as mining classroom dialogue patterns.

Multimodal Learning Analysis uses multiple methods to obtain and analyze data from different levels of learners,enabling more accurate and comprehensive insights into complex classroom learning processes.For example,integrating different modal data to establish regression models,diagnosing,detecting,and predicting non cognitive factors such as learning emotions,including the fusion of facial expressions and interaction features,the fusion of electrodermal activity and log data,the fusion of teacher-student dialogue,task progress,and the fusion of voice,self-report,and interaction features,providing personalized learning scaffolds and feedback.The artificial intelligence technology represented by the above research has brought dawn to break the dilemma of traditional classroom teaching research,while also facing many challenges.For example,Yan Hanbing and others found that there is still significant room for development in the development of standards for classroom teaching analysis,validation of improved results,human-machine collaboration,actionable insights,real-time feedback,and personalized recommendations in 41 studies on intelligent technology supporting classroom teaching.Indeed,the analysis and improvement of classroom teaching supported by artificial intelligence involve multiple links such as human-machine collaboration analysis standards,result validation,feedback and recommendation,which together form a complete loop.To achieve scientific and effective human-machine collaboration in this circuit,two key issues need to be addressed.Firstly,what kind of human-machine collaborative classroom analysis and improvement ideas will teachers accept and use in practice?Secondly,what kind of human-machine collaborative classroom analysis and improvement mechanism can be established to reflect the complementary advantages of human and machine intelligence?

3 Using Theory:Dual Path Learning to Determine Teachers'Practical Actions

When teachers are in a complex and uncertain educational field,the decision to adopt what teaching behavior is not entirely based on theoretical knowledge obtained from external inputs such as training and guidance.This is because their original habitual thinking,beliefs and values are difficult to easily change. The teaching behavior that is directly transformed into guiding practice is often the theory obtained through use.Agyris and Schein proposed the'use theory',which depicts the silent structure that dominates human behavior changes,and is a dual path learning approach,as shown in.

According to the perspective of usage theory,if there are multiple variables within a field of action,then the dominant variable is the value that the actor attempts to achieve,which determines the action strategy and brings behavioral consequences. If only correcting action strategies can bring about ideal behavioral outcomes,single path learning plays a role;When single path learning fails,teachers need to reflect and change the dominant variables that determine teaching philosophy,values,and beliefs,and then initiate dual path learning.The overall changes resulting from this will be more thorough,profound,and lasting.

There is a considerable similarity between"using theory"and"teacher practical knowledge".Teacher practical knowledge refers to the formation of teacher knowledge,which is more derived from the teacher's personal life history and educational practice on-site.Unlike theoretical knowledge obtained through learning,training,and other means,practical knowledge has characteristics such as practicality,situational nature,comprehensiveness,silence,and individuality.Dewey's pragmatism epistemology provides support for the"reasonable legitimacy"of teachers'practical knowledge at the theoretical level.This viewpoint is reflected in teachers and is a"practical knowledge"about the relationship between educational and teaching actions and their outcomes,with the function of guiding future actions.

Based on the above analysis,it can be seen that the theoretical knowledge that teachers are willing to accept and use in their actions is the result of the cross fertilization of single path and dual path learning.Teaching strategies determine teaching behavior,and the connection between the two belongs to single path learning;When the knowledge system or strategies acquired by teachers from practice cannot bring the expected results,it is necessary to change the dominant variables such as educational concepts and ideas,and enter a dual path learning.The existing artificial intelligence technology,if it only focuses on identifying the behavior results of teachers and students’actions,speech,cognition,etc.,and provides feedback and improvement at the level of teaching strategies,then it is circling in a single path learning.When single path learning fails,problems such as unreasonable standard formulation,unclear result validation,unclear human-machine collaboration,and inadequate personalized recommendations will be exposed.The method to solve such problems is to initiate dual path learning,allowing human-machine collaborative classroom teaching research to help teachers adjust the dominant variables.What are the dominant variables that can reflect educational ideas and concepts in classroom teaching?He Kekang pointed out that teaching structure is the external manifestation of educational concepts and ideas. It determines different classroom teaching structures based on the four elements and their relationships of teachers,students,teaching content,and teaching media in classroom teaching.It can be divided into two main teaching structures:"teaching centered""learning centered",and"teacher led student-centered".In the loop of classroom teaching analysis and improvement,teaching structure is the dominant variable,teachers’practical knowledge and teaching strategies belong to action strategies,while educational practice is the result of behavior.Therefore,the classroom research loop that teachers are willing to accept and apply to practice is an analysis and improvement that combines teaching structure and teaching strategies.Relying on the analysis results of teaching behavior,providing improvement suggestions for teaching strategies,can achieve single path learning;Analyzing and improving the dominant variables represented by the teaching structure involves initiating dual path learning.The two complement each other and together form an effective theory that teachers will use in practice.So,what kind of human-machine collaboration mechanism can be established to enable artificial intelligence to empower classroom teaching analysis and improvement is the second key issue that this article needs to face.

4 Man in the Loop:An Optimal Design Mechanism for Human Machine Collaboration

The essence of teaching improvement is to optimize design. Human in the loop is derived from the idea of engineering oriented optimization design.The term"people in the loop"refers to the participation of people in design iterations,with the aim of utilizing the advantages of"people"being better at comprehensive and fuzzy judgment than machines,combining manual experience with automatic optimization,making the optimization results more in line with engineering practice requirements and improving optimization efficiency.This idea has been applied in fields such as aircraft design,missile launch,and simulated driving.Reflecting on the traditional classroom teaching analysis and improvement process,it can be found that not only"people are in the loop",but also"people are the entire loop".The quality of classroom teaching analysis and improvement depends on the individual experience,understanding,and even personality of teachers,leading to a subjective and inefficient approach to the collective growth and inheritance of experience among teachers.When artificial intelligence first enters classroom research,it relies on algorithms for classroom behavior recognition,attention monitoring,participation analysis,and provides diagnostic reports.Based on this,teachers can make improvements,which can easily exclude people from the automatic analysis and optimization loop,leading to"people not in the loop".Therefore,there is a lot of development space for issues such as"validation of change results,human-machine collaboration,actionable insights,real-time feedback,and personalized recommendations",As expected.Drawing on the optimization design concept of human in the loop,distinguishing which loops require human participation,which loops can be handed over to machines,and which loops require the combination of manual experience and automatic analysis,establishing a human-machine collaboration mechanism,has become the key to empowering classroom teaching research with artificial intelligence technology.According to the dual path learning model of usage theory,the research loop for classroom teaching analysis and improvement can be divided into low intervention areas and high intervention areas,as shown in.Low intervention refers to the clear and computable rules of teaching analysis,rich and matching teaching improvement strategies,and a low proportion of human intervention provided by experts and teachers.For example,computer vision technology can analyze classroom teacher-student behavior,natural language understanding technology can analyze classroom discourse and Q&A,and knowledge graph or reasoning graph can analyze classroom cognitive level.After machine automatic analysis,it was found that the practical effect was not good,and it can be matched with abundant teaching strategies,teaching methods,teaching cases,etc.in the field of education,such as increasing the proportion of students'autonomous learning and exploratory learning behavior;Teachers should adjust their questioning methods and techniques,reduce shallow questions such as"yes,right,not good",and appropriately add questions such as"how to do it,why,and what are the possibilities"to stimulate students'deep thinking;Establish the correlation between current knowledge and students'pre existing knowledge base,redesign the lead organizer,provide a framework for the availability,distinguishability,stability,etc.of cognitive structural variables,and use teaching strategies to guide behavior improvement.High intervention prediction refers to the analysis of fuzzy rules,and existing improvement strategies cannot directly solve practical problems. It is necessary to generate and transform implicit strategies into explicit strategies,or adjust dominant variables such as teaching structure,in order to solve practical difficulties.This analysis process is highly dependent on experts or teachers,and can be analyzed by machines first.Based on this,humans can provide solutions.For example,in a certain part of the classroom,if the teacher lectures too much,whether it is necessary to analyze the key and difficult points or excessive indoctrination teaching,it needs to be analyzed based on the actual situation.Facing different teaching objectives or learners,the same teaching activity will have different analysis results and improvement suggestions.In the classroom teaching analysis and improvement loop,single path learning is adopted in the low intervention area,where machine intelligence leverages its technological advantages to analyze the classroom on a large scale,quickly,and accurately.Mature,stable,and explicit teaching strategies are used to guide teachers in improving behavioral outcomes;High risk areas need to initiate dual path learning,mainly relying on human unique teaching art and wisdom,to help teachers change teaching concepts,teaching structures,and other dominant variables,guide the generation of implicit,flexible,comprehensive,and adaptable teaching strategies,and then combine them with existing explicit strategies to jointly guide teaching practice and bring about in-depth and long-term teaching improvement. Therefore,the use of theoretical dual path learning,coupled with the optimization design of human in the loop,together constitute a human-machine collaborative mechanism for classroom teaching analysis and improvement.

5 Analysis and improvement model of human-machine collaboration in classroom teaching

The key element for effectively improving education and teaching is to form a cohesive and effective improvement process from problem characterization to scientific attribution,and then to problem-solving strategies.After clarifying the mechanism of human-machine collaboration,this article proposes a full loop model for analyzing and improving human-machine collaborative classroom teaching,as shown in.The full loop model is divided into TESTII classroom teaching points.

Analysis model and 4A teaching improvement model.Both models use"teaching structure"as the dominant variable.For the analysis model,teaching structure analysis is the endpoint,and human-machine collaboration is used to analyze teaching behavior,teaching strategies,and teaching structure.For improving the model,teaching structure analysis is the starting point.Adjusting the current teaching structure,changing the dominant variable,and then improving teaching strategies and teaching behaviors. Then,the practical results are inputted into a new round of teaching analysis,Implement loop iterative optimization.The model is divided into low intervention and high intervention areas to distinguish the areas where machine intelligence and human intelligence play a major role.However,the two areas are not completely separated,and there will be some overlapping areas,representing the spiral creation process of practical knowledge from implicit to explicit,which is the interaction area of human intelligence and machine learning swarm intelligence.

5.1 TestII Classroom Teaching Analysis Model

The artificial intelligence classroom teaching analysis model proposed by our team takes teaching events as the basic analysis dimension,with teaching structure as the analysis goal,and adopts artificial intelligence technologies such as computer vision and natural language understanding.It includes stages such as teaching event recognition and teaching stage division,teaching method structure sequence,time sampled behavior and speech interaction analysis,evidence-based teaching interpretation,and human-machine collaborative teaching improvement,Construct a Teaching Events,SPS,Time Coding,Interpretation,Improvement)model for classroom teaching analysis.Below is a brief introduction to the five stages in the model.

Stage 1:Identify nine major teaching events and classify them into different teaching stages(Teaching Events Identify and

Classify)

The smallest design and implementation unit commonly used by teachers in classroom teaching is teaching activities.Gane believes that only teaching activities that point to effective cognitive processing of students are meaningful teaching activities,called teaching events.Therefore,this model takes the nine major teaching events proposed by Gane as the dimensions of classroom teaching analysis.By utilizing computer vision technology and natural language understanding technology,multimodal analysis is conducted on classroom teaching videos and instructional design scheme texts to identify teaching events and divide them into common teaching stages such as introduction and new teaching.

Stage 2:Analyzing the Sequencing of Pedagogical Structure(SPS)in the teaching stage

Referring to the structural sequence of teaching methods proposed by scholars such as Jacobson,the teaching methods in different teaching stages are divided into high structured H(teacher based teaching)and low structured L(student based discovery learning)based on the proportion of teacher guidance. Technically,natural language understanding technology is used to establish a teaching method structural sequence classifier.By modeling the sentences and chapters in the classified text data,the structural sequence is obtained.

Stage 3:Time Sampling Interactive Coding for Speech and Behavior in Different Structural Sequences

The TEST II framework conducts time sampling within different structural sequences to analyze the teacher-student behavior and language interaction within the sequence,providing evidence for precise improvement.Technically,Word2vec,a deep learning model for natural language understanding,and object monitoring technology based on deep convolutional neural networks are first used to analyze speech and behavioral interactions within structural sequences.Then,teachers or researchers combine the analysis results to comprehensively judge the roles of teachers and students in different teaching structural sequences and teaching stages.

Stage 4:Combining existing educational and teaching theories,interpreting and analyzing results based on evidence(Interpretation)

The TEST II model provides classroom teaching analysis reports at this stage,such as a map of the number and time distribution of teaching events in a class,the results of teaching stage division corresponding to the events,and a sequence of teaching method structures generated by stages.Based on the above data,determine whether the actual teaching structure used in this course is teaching centered,learning centered,or teacher led student-centered.

Stage 5:Based on the interpretation results,entering the classroom teaching improvement stage,the endpoint of analyzing the model is to determine the teaching structure of this lesson,which is also the starting point for improving the model.

5.2 4A classroom teaching improvement model

Improvement Science is a problem-solving method centered on continuous exploration and learning,which has been widely applied in fields such as management,health,and manufacturing. This method can help organizations clarify how the system works and what actions can be taken to improve overall organizational performance.Some scholars believe that improving science in the field of education requires two types of knowledge,namely basic knowledge of specific disciplines and complex knowledge systems. The former mainly comes from learning educational theory,while the latter needs to summarize and sublimate from problems in practice,and achieve improvement through iteration.It can be seen that improving science from another perspective also validates the viewpoint of using theoretical and teacher practical knowledge.

Based on the above analysis,this article divides the human-machine collaborative classroom teaching improvement model into four stages,namely Structure Analysis,Problem Addressed,Strategies Adjusted,and Practical Application.

Stage 1:Teaching Structure Analysis

As the central and connecting point for classroom teaching analysis and improvement models,the main purpose of this stage is to determine whether the current classroom teaching structure is reasonable,and then let human teachers choose the appropriate teaching structure based on teaching objectives and learner characteristics.The improvement suggestions in this stage are mainly completed by human expert teachers.Research has found that the dual main teaching structure of teacher led and student led has gained widespread consensus in the education industry. However,in daily classroom communication or in national classroom teaching competition cases,a considerable portion of classrooms still adopt a teaching centered teaching structure,with a high proportion of teacher lecture students listening and teacher demonstration students practicing in the classroom.This indicates that there is still a gap between theoretical acceptance and practical application of the dual main structure.Therefore,relying mainly on human experts such as expert teachers or teaching research groups to help teachers judge and reposition dominant variables such as educational concepts and teaching structures has become a crucial stage for effective teaching improvement.The specific forms can be face-to-face or remote,synchronous or asynchronous teaching and research exchanges,or theoretical training mainly based on case analysis and task driven methods.

Stage 2:Problem Addressed

Teaching mode is a reflection of specific educational and teaching concepts and ideas,the basic structure of teaching activities guided by certain teaching and learning theories,and a concise and stable combination of teaching activities and strategies.Different teaching structures lead to different teaching modes,each with specific steps and sequences.The teaching structure is divided into three types:teaching as the center,learning as the center,and leading subject.The number of teaching models is extremely rich,and their manifestations are also diverse.Many teachers agree with the dominant teaching structure,but when the effectiveness of teaching practice is poor,the problem is likely to occur in the improper selection or implementation of teaching modes.Therefore,at this stage,machines cannot replace humans in providing solutions. In most cases,it is still necessary to rely on various forms such as human experts or teacher peers or self reflection,using literature research,historical research,design based research,and other methods to help teachers identify problems and re select or design teaching modes based on the adjusted teaching structure.

Stage 3:Strategies Adjusted for Strategy Improvement

Teaching strategies refer to a series of teaching methods and behaviors adopted in the teaching process to achieve certain teaching objectives.Compared to patterns,strategies are more diverse and flexible.A teaching mode is a combination of multiple strategies,and the same strategy can be applied to different modes. In classroom teaching,teaching strategies are the most dynamic methods and means that can directly affect teaching behavior. If teaching strategies are viewed as a knowledge base,there are both stable achievements that have condensed human educational wisdom for thousands of years,as well as new forces that keep up with the times and are dynamically generated.From the perspective of SECI knowledge management theory proposed by Ikujiro Nonaka and others,the knowledge base continues to experience a spiral creation process from individual to group,from recessive to explicit,from socialization,characterization,connection and internalization.

At this stage,human intelligence and artificial intelligence need to work together.For scenarios that have been clearly applied and have been experimentally tested to have good results,explicit strategies can be accurately matched and personalized recommended by artificial intelligence based on the teaching deficiencies found in the analysis results;If the existing explicit strategies cannot be directly applied,they need to be remodeled or created to transform the implicit strategies into explicit ones,or from individual experience to group experience,in the form of teacher practice community,learning community,hybrid teaching research and other forms,using crowdsourcing,federal learning and other swarm intelligence discovery technologies,through task allocation,quality control,expert discovery and other key algorithms,Provide improvement strategies for the synergy between artificial intelligence and human intelligence.

Stage 4:Practical Application

When teachers clarify the dominant variables such as teaching structure and have improved teaching models and strategies,they can implement teaching improvement from dimensions such as language interaction,problem hierarchy,teacher-student behavior,and technology application.The practice at this point is a specific application guided by dominant variables and action strategies,which can adopt algorithm recommended strategies and cases,and can also be flexibly adjusted to adapt to real learning situations.According to the teaching practice implemented in the improvement plan,the next round of teaching analysis can be carried out for iterative optimization of human-machine collaboration.In the classroom teaching analysis and improvement model,different educational research methods and artificial intelligence technologies can be adopted at each stage.As shown in.In the TEST II analysis model,the low intervention area can be mainly composed of intelligent technologies such as computer vision,self speech recognition conversion,natural language understanding,knowledge graph,etc.,to identify and calculate the explicit behavior,speech,cognition,emotion,etc.of teachers and students.Through multimodal analysis,it provides a basis for structural sequences with teaching significance,judgment of teachers and students’roles,etc.In the high intervention area,the voice thinking method is used Focus group interviews and other educational research methods are used to form evidence-based teaching structure judgments.In the 4A teaching improvement model,the improvement of the high calibre pre zone is still based on human intelligence,using educational research methods such as literature research,historical research,and design based research to reposition the teaching structure,select teaching models,and create or transform new teaching strategies.In the low calibre pre zone,research methods based on artificial intelligence can be used to find algorithms through swarm intelligence such as crowdsourcing and federal learning,Recommend personalized teaching improvement strategies.Teachers can focus on improving one or more aspects such as speech,question and answer,behavior,and technology application as needed,and then verify the effectiveness of improvement through action research,case studies,etc.

6 Conclusion

The improvement of classroom teaching quality cannot be separated from scientific and effective classroom teaching analysis and improvement.One of the key points of promoting the construction of the teaching team with artificial intelligence is to optimize classroom teaching using intelligent technology.This study is based on usage theory and human in loop design optimization,and proposes a"teaching structure"as the focus.The classroom teaching analysis and improvement loop is divided into high intervention and low intervention areas.Through the TEST II classroom teaching analysis model and the 4A improvement model,an overall solution for human-machine collaboration to improve the quality of classroom teaching is constructed.

Indeed,there are many challenges to be faced in this process. For example,establishing a common case set of classroom teaching with rich types and reasonable samples,sharing algorithm codes for computer vision and natural language understanding that can be used for classroom behavior and speech analysis,establishing an open,co built and shared library of teaching problems and improvement strategies,and a teacher practice community that can be used for crowdsourcing discovery and federated learning are all issues that need to be broken through in the field of human-machine collaborative classroom teaching research.

Reference

[1]Sun Zhong,Lv Kaiyue,Luo Liming,Chen Meiling,Xu Lin,Shi Zhiping Analysis of Classroom Teaching Based on Artificial Intelligence[J]. China Electronic Education,2020(4):15-23.

[2]Ministry of Education.Opinions on Strengthening and Improving the Teaching and Research Work of Basic Education in the New Era[J]. State Council Bulletin of the People's Republic of China,2020(8):69-72.

[3]WATANABE E,OZEKI T,KOHAMA T.Analysis of interactions between lecturers and students[C]//Proceedings of the 8th International Conference on Learning Analytics and Knowledge.Association for Computing Machinery.New York:United States,2018:370-374.

[4]SPREEUWENBERG R.Does emotive computing belong in the classroom[J].EdSurge,2017.

[5]ROUAST P V,ADAM M T P,CHIONG R.Deep learning for human affect recognition:Insights and new developments[J].IEEE transactions on affective computing,2019,12(2):524-543.

[6]Ma Yuhui,Xia Xueying,Zhang Wenhui Research on the Analysis Method of Teacher Classroom Questions Based on Deep Learning[J]. Research on Electronic Education,2021,42(9):108-114.

[7]Guo Jiong,Rong Qian,Hao Jianjiang Summary of Research on the Application of Artificial Intelligence in Teaching Abroad[J].Research on

Electronic Education,2020,41(2):91-98107.
[8]Cao Yiming,Song Yu,Zhao Wenjun,Li Mingxuan Research on the Construction of Artificial Intelligence Evaluation System for Mathematics Classroom Dialogue in Education 2030[J]Journal of Mathematics Education,2022,31(1):7-12.
[9]BLIKSTEIN P,WORSLEY M.Multimodal learning analytics and education data mining:using computational technologies to measure complex learning tasks[J].Journal of learning analytics,2016,3(2):220-238.
[10]Mou Zhijia.Multimodal Learning Analysis:New Growth Points in Learning Analysis Research[J].Research on Electronic Education,2020,41(5):27-32,51.
[11]MUDRICK N V.Designing adaptive intelligent tutoring systems:fostering cognitive,affective,and metacognitive self-regulated learning processes using multimodal,multichannel process data[D].Raleigh:North Carolina State University,2018.
[12]BOSCH N,D'MELLO S K,OCUMPAUGH J,BAKER R S,SHUTE V.Using video to automatically detect learner affect in computer-enabled classrooms[J].ACM transactions on interactive intelligent systems,2016,6(2):1-26.
[13]KAPOOR A,BURLESON W,PICARD R W.Automatic prediction of frustration[J].International journal of human-computer studies,2007,65(8):724-736.
[14]GRAFSGAARD J F,WIGGINS J B,VAIL A K.The additive value of multimodal features for predicting engagement,frustration,and learning during tutoring[C]//Proceedings of the 16th International Conference on Multimodal Interaction.Association for Computing Machinery.New York:United States,2014:42-49.
[15]EZ-ZAOUIA M,LAVOUÉE.EMODA:a tutor oriented multimodal and contextual emotional dashboard[C]//Proceedings of the Seventh International Learning Analytics&Knowledge Conference.Association for Computing Machinery.New York:United States,2017:429-438.
[16]Yan Hanbing,Zhao Jiabin,Wang Wei Diagnosis of classroom teaching empowered by technology:characteristics and development space[J]Modern Distance Education,2022(2):4-11.
[17]Chris Achilles et al.Action Science:Concepts,Methods,and Skills of Exploration and Intervention[M].Beijing:Education Science Press,2012.
[18]Wang Ying,Wang Qiong Design and Practice of Dual Path Learning Based on Moodle-Taking Interactive Electronic Whiteboard Network Training for Primary and Secondary School Teachers in China as an Example[J]China Electronic Education,2015(11):84-91.
[19]Chen Xiangming,Zhao Kang From Dewey's pragmatism epistemology to see teachers'practical knowledge[J]Education Research,2012(4):108-114.
[20]He Kekang.Theoretical Reflection on the Integration of Information Technology and Curriculum[J]Information Technology Education in Primary and Secondary Schools,2002(Z1):27-36.
[21]Li Runze,Zhang Yufei,Chen Haixin The evolution and development of the concept of "people in the loop"in aircraft aerodynamic optimization design[J]Journal of Aerodynamics,2017,35(4):15.
[22]Yang Yalian,Wang Lei,Yang Guo,Hu Xiaosong Research and development of a human driving simulation experimental system in the loop[J]Journal of Chongqing University,2015,38(4):38-44.
[23]Hu Qingfang Reconstruction of classroom teaching diagnosis improvement system[J].Ideological and Theoretical Education,2009(4):41-47.
[24]Sun Zhong,Lv Kaiyue,Shi Zhiping,Luo Liming TestII Framework:The Development Trend of Artificial Intelligence Supporting Classroom Teaching Analysis[J].Research on Electronic Education,2021,42(2):33-39,77.
[25]GAGNÉR M.The conditions of learning[M].4th ed.New York:Holt,Rinehart&Winston,1985.
[26]JACOBSON M J,KIM B,PATHAK Z,ZHANG B H.To guide or not to guide:issues in the sequencing of pedagogical structure in computational model-based learning[J].Interactive learning environment,2013,23(6):715-730.
[27]LEMAHIEU P G,BRYK A S,GRUNOW A,GOMEZ L M.Working to improve:seven approaches to improvement science in education[J].Quality assurance in education,2017,25(1):2-4.
[28]LANGLEY G J,MOEN R D,NOLAN K M,et al.The improvement guide:a practical approach to enhancing organizational performance[M].2nd ed.San Francisco:John Wiley&Sons,2009.
[29]Zhong Qiquan The Characteristics of Teacher Professional Development from the Perspective of SECI Theory[J]Global Education Outlook,2008(2):7-14.
[30]Tong Yongxin,Yuan Ye,Cheng Yurong Overview of spatiotemporal crowdsourcing data management technology research[J]Journal of Software Science,2017,28(1):35-58.
[31]Yang Qiang,Tong Yongxin,Wang Yansheng,Fan Lixin,Wang Wei,Chen Lei,Wang Wei,Kang Yan Overview of federated learning algorithms in swarm intelligence[J]Journal of Intelligent Science and Technology,2022,4(1):29-44.