Design of Evaluation Index System for Smart Classroom Learning Activities Based on Multimodal Data

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Abstract. Under the background of education informatization in China, smart classroom is one of the research hotspots in the field of education. In smart classroom, students' learning activities involve a variety of data sources. Based on the evaluation index system of smart classroom learning activities, this paper evaluates students more comprehensively through multi-dimensional evaluation of students' learning process. The evaluation index system is helpful to improve the scientificity and objectivity of students' learning evaluation. It plays an important role in breaking the stubborn disease of score-only learning evaluation in current education and teaching, providing targeted teaching suggestions for teachers, and promoting students' learning progress and teachers' teaching quality.

Keywords: multi-modal data · intelligent classroom · learning activity · evaluation index

1 Introduction

With the rapid development of digital education, smart classroom has become the trend of future education development. In the smart classroom, students' learning process and performance can be recorded and analyzed through various forms of data [1–4]. These multi-modal data include text, voice, image, video and other forms, which can provide more comprehensive and accurate learning evaluation results, help teachers better understand students' learning situation, improve teaching effect and promote students' academic growth [5, 6]. Based on the diversity of students' learning activity data in smart classroom, this paper attempts to construct a set of evaluation index system of smart classroom learning activities based on multimodal data, explores the scientificity of evaluation index of smart classroom teaching based on multimodal data, and provides theoretical support and practical exploration for smart classroom research under the background of big data.

F. Huang et al. (Eds.): ICAIE 2023, AHCS 15, pp. 345–356, 2024.
https://doi.org/10.2991/978-94-6463-242-2_43

2 Determination of Evaluation Index Elements of Smart Classroom Learning Activities Based on Multimodal Data

The data generated by students in the process of learning is multimodal. How to collect and analyze these multimodal data is the key to strengthening process evaluation. Each source or form of information can be called a modality [7]. By collecting students' multimodal data, students can be comprehensively analyzed and evaluated from multiple perspectives and elements, so as to improve the accuracy and credibility of teaching evaluation. Therefore, this paper divides the multimodal data in the smart classroom into several indicators of learning activity evaluation.

2.1 Design Principles of Learning Activity Evaluation Index System

The design principle is the basic principle that must be followed in teaching evaluation to ensure the effectiveness, fairness and feasibility of evaluation, so as to provide support for teachers' teaching improvement. These principles include the principle of objectivity, scientific principles, the principle of integrity, guiding principles, development principles.

1) The principle of objectivity
Japanese education evaluation expert Tanaka said in the book "education evaluation" that the teaching evaluation should follow the principle of objectivity, evaluation criteria, methods, evaluators' attitudes, and evaluation results must be consistent with the objective reality. The purpose of teaching evaluation is to provide objective value judgment for students' learning and teachers' teaching. Without objectivity, the meaning of evaluation will be lost, which may lead to errors in teaching decision-making. The evaluation index of learning activities needs to be evaluated by objective criteria to avoid the interference of subjective factors.

2) Scientific principles
The evaluation index of learning activities should be based on the mainstream educational theory and research results, which is scientific and practical. Professor Hu Zhongfeng believes that in teaching evaluation, advanced measurement techniques and statistical methods should be used, and various data obtained should be strictly processed according to scientific evaluation procedures and methods, rather than subjective judgment based on experience and intuition [8].

3) The principle of integrity
Professor Wang Xiaogen believes that a complete education evaluation system must involve all aspects of the entire education process, and all aspects of learning activities must be taken into account when carrying out student evaluation [9]. It is necessary to make a multi-angle and comprehensive evaluation of all aspects of students' classroom learning behavior, rather than point instead of surface, generalization [10].

4) Guidance principle
Professor Cai Baolai believes that evaluation and guidance should be combined when evaluating students' learning behavior. Through careful analysis of the evaluation results, find out the causal relationship, confirm the reasons, and guide students to clarify the direction of future efforts through timely, specific and enlightening information feedback [11].

5) Developmental Principle
Professor Chen Mingxuan believes that learning evaluation is the compass of education and should play the essential function of evaluation to promote students' development. The evaluation of students' learning behavior is a means to encourage students and teachers and promote teaching improvement. Therefore, evaluation should focus on students' learning progress and dynamic development, while focusing on teachers' teaching improvement and ability improvement. In addition, when designing the learning activity evaluation scale, we should also pay attention to the practicability and operability of the scale.

2.2 The Method of Determining the Evaluation Index Elements of Learning Activities

The evaluation of multi-modal learning activities in smart classroom focuses on contextuality. The process of evaluation should consider the real situation of students' learning. In addition, setting the weight of evaluation indicators requires multiple experts to evaluate and assign weights. Therefore, this paper uses the following three analysis methods:

1) Questionnaire method
Questionnaire survey is a common method of collecting and analyzing data in the field of social science. In this study, 28 experts in the field of educational technology were selected to study the classroom learning activities of undergraduates majoring in educational technology, and to study the rationality of the hierarchical structure model initially constructed for the evaluation of students' learning activities in the smart classroom. A total of 28 questionnaires were distributed, with a recovery rate of 100%. Several objects with different opinions on the first draft of the evaluation index were selected for interviews. Combined with the survey results and interview conclusions, the evaluation index system of learning activities was continuously optimized to obtain the optimal hierarchical structure model. By analyzing the questionnaire data, the reliability of the learning activity evaluation scale was tested.

2) Experts evaluating
The expert evaluation method, also known as the Delphi method, can also be called the expert group method or the expert opinion consultation method according to its form. It is to solicit opinions on a certain issue from experts in the form of anonymous investigation. After summarizing and sorting out, the results are returned to the experts again for the next round of collection, repeated several times until the opinions of the experts tend to be consistent. In this study, two rounds of expert questionnaire survey were conducted on the multi-modal evaluation index system of smart classroom, and each evaluation index system was revised repeatedly to reach a consensus.

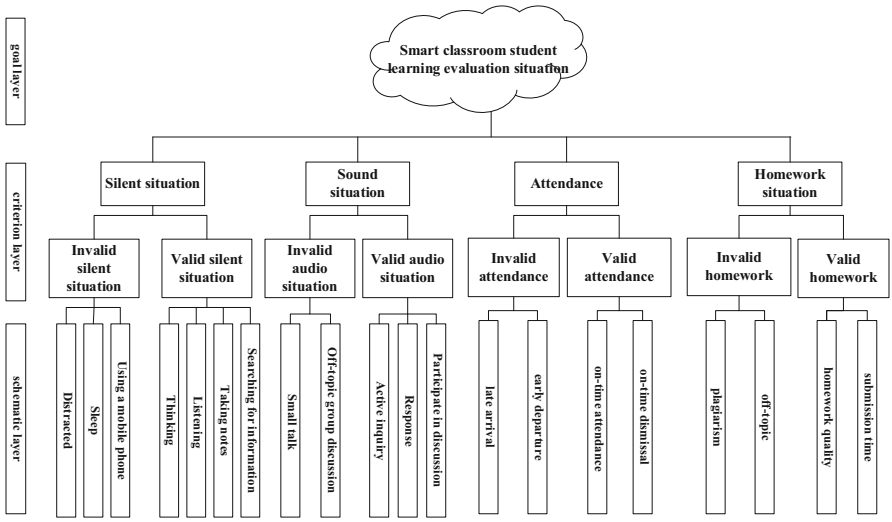

Fig. 1. Hierarchical Structure Model

2.3 Establish a Hierarchical Structure Model

This study is based on the design principles of teaching evaluation as the theoretical basis, based on the literature method, situational analysis method, expert interview method, questionnaire survey and other methods, to develop a learning activity index system. Firstly, according to the situation analysis method, the first-level indicators of learning activity evaluation are divided into two learning activity situations: silent situation and sound situation. Through questionnaire distribution and expert interviews, the first-level indicators of students' learning activities in the smart classroom are optimized into four, namely silent situation, sound situation, attendance, homework, etc. These four first-level indicators fully cover all activities in the classroom. The final optimization results are shown in Fig. 1.

2.4 Homogeneity Reliability Test

Homogeneity reliability refers to the test of the same degree of content or trait, which mainly examines whether the evaluation item measures the same concept and whether there is a high internal consistency between the measured items. The higher the homogeneity reliability, the stronger the credibility of the evaluation results. At present, the most commonly used consistency method is the Cronbach's alpha coefficient method. The formula is:

$$\alpha = \left[\frac{K}{K-1}\right]\left[1 - \left(\sum S_i^2\right)/\left(S_x^2\right)\right]$$

This study uses the above formula to test the reliability value of the rationality questionnaire of the evaluation index system. Among them, K is the total number of questions in the questionnaire, S2i is the intra-item variance of the score of question i in the

questionnaire, and S2x is the variance of the total score of all questions in the questionnaire. When the correlation degree of each question is greater, the reliability coefficient of Kronbach is greater, and the internal consistency reliability of the questionnaire is higher.

Using SPSS26.0 as a statistical analysis tool, $\alpha = 0.956$ was calculated. It shows that the rationality questionnaire of students' classroom learning activity evaluation scale has high reliability.

2.5 Analysis of Learning Evaluation Index Elements

The following will introduce the elements of the criterion layer and the scheme layer of the hierarchical structure model in detail.

1) Silent situation (x1)
Silent situation refers to the situation where students do not communicate in the smart classroom. The silent situation of students' multimodal data in the classroom is summarized as invalid silent situation and effective silent situation.

a) Invalid silent situation (y1). In the smart classroom, the invalid silent situation means that the students do not focus on learning in the classroom and are not born. The index is divided into the following three situations: Mind wandering: students' attention is difficult to focus on the content of the teacher's lectures, and there are phenomena such as distraction, scattered thinking, wandering eyes, and frequent shifting postures; Sleep: students doze off and sleep during class; Look at mobile phones: Use mobile phones to carry out activities unrelated to course learning. This kind of situation shows that students may lack positive participation spirit, or lack self-confidence, and need teachers' guidance and help.
b) Valid silent situation (y2). In the process of learning, students use non-verbal ways, such as body, expression, action to express their thoughts, understanding, mood, attitude and so on. These silent situations reflect students' positive and effective learning state. The indicator is divided into the following four situations. Thinking: students can focus on listening in the classroom and respond positively to the problems thrown by teachers; listening: listen carefully to the speeches of teachers and class members, and carefully watch the video and audio played in the smart classroom; note-taking: Students take notes and type in classroom learning activities. It is a process of learning and thinking, which helps to deepen the understanding and memory of knowledge. Search: Use appropriate tools (such as books, the Internet, etc.) to search for relevant literature, documents, data, records, etc. Effective silent situations can promote the interaction and effectiveness of teaching and improve students' learning experience and effectiveness.

2) Voiced situation (x2)
Voiced situation refers to the situation with voice or verbal communication in smart classroom. The audio situation of students' classroom multimodal data is summarized as invalid audio situation and effective audio situation.

a) Invalid voiced situation (y3). In the process of learning activities, students have a voice state, but the content of expression is not related to learning activities. The index is divided into the following two situations, chatting: in the classroom, students communicate with each other on topics related to non-classroom learning, and unrestrained chatting will interfere with classroom order and affect students' learning effect; group discussion deviates from the theme: In a group discussion, students do not understand the content of the discussion arranged by the teacher, contribute no opinions on the content of the discussion, or respond when the teacher asks questions to deviate from the content of this discussion, requiring teachers to remind and guide.
b) Valid voiced situation (y4). In the process of students' learning activities, the sounds in the learning scene are helpful to promote students' learning. The index is divided into the following three situations, active questioning: in the teaching process, students take the initiative to ask questions related to the theme of learning activities. This situation can reflect students' learning activities of independent thinking; response: including active response and passive response. The difference between active response and passive response lies in students' attitude and initiative. Active response refers to students' initiative to answer questions or spontaneously propose solutions to problems; passive response means that students respond to questions after being asked by name. Active respondents are usually more active than passive respondents, and are more likely to fully understand the background of the problem and master the knowledge points; participation in discussion: including active participation in discussion and passive participation in discussion, the difference is that students' initiative and communication effect. Active participation in discussion means that students spontaneously put forward topics, opinions or provide new ideas according to the discussion content issued by teachers, and actively interact and communicate with other students. This way of participation can promote communication, thinking and innovation, and is conducive to finding and solving problems. Passive participation in discussion means that students are invited or asked to participate in the discussion, but they do not have their own topics or have no positive willingness to participate, only listen to or follow the views of others. This kind of participation is usually not conducive to in-depth thinking and communication, which is easy to cause the communication content to be monotonous and boring, lack of freshness and heat.

3) Attendance (x3)

Attendance refers to the students during the learning activities, appear in a predetermined location, ready to start learning. Attendance is usually through the way of check-in, attendance can usually reflect the students' attitude towards learning. The attendance of students' classroom multimodal data is summarized as invalid attendance and effective attendance.

a) Invalid attendance (y5). Invalid attendance refers to students' failure to enter the classroom on time. The indicator is divided into the following two situations, late: students do not enter the course within the specified time, but enter the course for a period of time after the course begins; early exit: students leave the classroom early

and do not end the course within the specified time. These two cases will affect the students' learning effect and teaching quality.

b) Valid attendance (y6). Effective attendance means that students can appear in the classroom according to the prescribed time and participate in classroom learning activities. The indicator is divided into the following two situations, class on time: including entering the classroom on time (arriving in the classroom within ten minutes before class), and arriving in the classroom early (arriving in the classroom ten minutes or more in advance); timely class: including the phenomenon of timely class and late withdrawal due to continuous learning activities.

4) Homework situation (x4)

Homework refers to the learning tasks or exercises assigned to students in the course, aiming to enable students to consolidate and apply the knowledge they have learned, cultivate learning habits and solve problems. The homework of students' multimodal data in class is summarized as invalid homework and effective homework.

a) Invalid homework (y7). It refers to the homework that the students hand in does not meet the requirements of the teacher, does not submit on time or the quality is not up to standard. These assignments may not achieve the corresponding learning objectives, cannot improve students' academic level or cannot help students consolidate what they have learned. Ineffective homework will lead to teachers' inability to accurately evaluate students' learning effects, and will also waste the time and energy of students and teachers. The index is divided into the following two situations, plagiarism: copying and pasting the answers in other people's works or web pages directly or changing individual words without independent thinking; theme deviation: the content of the answer deviates from the direction of the question, such as no clear theme, unclear logic or meaningless homework. Jobs with high error rate, or errors in basic concepts.

b) Valid homework (y8). Students complete a certain quality and quantity of homework according to the requirements of teachers, and these homework meet the learning objectives and standards, which can support students' learning and improve their academic level. Consolidate the knowledge learned through homework exercises to improve students' understanding and application of the course. In the smart classroom, teachers can evaluate students' mastery and understanding of the course through the assignments submitted by students, and then make targeted education and teaching plans to help students learn better. The index is divided into the following two situations, the quality of the work: not only the progress of the completion of the work and the number of tasks completed, but also the students' understanding of the subject, the degree of mastery of knowledge and skills, and the innovation and method of solving the problem. Submission time: Students should submit their homework before the deadline and try not to delay the time. The quality and submission time of students' homework can reflect students' attitude and seriousness towards learning.

3 The Calculation of Evaluation Index Weight of Smart Classroom Learning Activities Based on Multimodal Data

3.1 Expert Weight Scoring

This study sends index weight questionnaires to seven experts in the field of educational technology, and uses expert consultation method and analytic hierarchy process (AHP) to sort out the weight of each index. Seven experts assign weights to the secondary and tertiary indicators of the first-level indicators according to the importance of each weight.

3.2 Establish Judgment Matrix

According to the weight assignment of each level index by seven experts, the judgment matrix $[a_{ij}]$ n*n is obtained, see Table 1. According to the Saaty scale method proposed by American mathematician Thomas L. Saaty in 1977, the relationship between indicators at all levels is described, the relative importance of different factors is judged, and the relative priority is determined. (a_{ij}: Comparison of the importance of factor a_i and factor a_j).

3.3 Reliability Analysis

Consistency test must be carried out when using judgment matrix to calculate weight. The consistency index CR (A) = (λmax(A)-n)/(n-1) RI of judgment matrix A is defined, RI is the random consistency index; if CR (A) ≤ 0.1, then A is a consistent matrix; if CR (A) > 0.1, then matrix A is inconsistent. Here, λmax (A) is the principal eigenvalue of matrix A. Check the consistency of the judgment matrix and pass the consistency test.

3.4 Determination of Relative Weight of Expert Evaluation Level

It is assumed that m experts score the weight of the evaluation index of students' learning activities, and there is a difference between the scale value a of each expert's weight. When comparing each two indicators, there should be an optimal scale value a_{ij}^* objectively. The geometric average method is used to calculate the optimal scale value a_{ij}^* of the kth expert. The calculation formula is as follows;

$$a_{ij}^* = \prod_{k=1}^{m} (a_{ij}^k)^{\frac{1}{m}}$$
$$(i, j = 1, 2, \ldots, n,\ k = 1, 2, \ldots, m)$$

By judging the minimum variance between the scale value and the optimal value, the relative weight of the expert's evaluation level is determined. The smaller the variance between the scale value and the optimal value, the higher the proportion of the weight.

Table 1. Expert Judgment Matrix

	x1/x2	x1/x3	x1/x4	x2/x3	x2/x4	x3/x4	y1/y2	y3/y4	y5/y6
a1	1	1	1	1	1	1	21/29	2/3	1
a2	7/3	7/3	1	1	3/7	3/7	3/4	7/8	7/8
a3	3/2	3/2	1	1	2/3	2/3	1	7/13	1/3
a4	5/2	5	5/2	2	1	1/2	3/7	1	1
a5	1	2	2/5	2	2/5	1/5	1	3/7	2/3
a6	2/3	1	2/3	3/2	1	2/3	1	1	1
a7	1	3/2	3/2	3/2	3/2	1	1/2	1/2	1
	y7/y8	z1/z2	z1/z3	z2/z3	z4/z5	z4/z6	z4/z7	z5/z6	z5/z7
a1	1	1	2/3	2/3	8/7	8/7	8/7	1	1
a2	3/4	1	1	1	6/5	3/2	6/5	5/4	1
a3	1/2	7/10	7/13	10/13	1	8/7	8/7	8/7	8/7
a4	1	1	1	1	1	10/7	5/4	10/7	5/4
a5	2/3	1/2	1/2	1	1	3/2	3/2	3/2	3/2
a6	1	1/2	1/2	1	1	3/2	3/2	3/2	3/2
a7	1	2	1	1/2	7/3	7/3	1	1	3/7
	z6/z7	z8/z9	z10/z11	z10/z12	z11/z12	z13/z14	z15/z16	z17/z18	z19/z20
a1	1	1	1	1	1	1	1	1	1
a2	4/5	5/2	3/2	1	2/3	1	1	2/3	3/2
a3	1	1	5/3	1	3/5	1	8/7	1	1
a4	7/8	3/2	4/3	4/3	1	1	1	2/3	3/2
a5	1	2	5/4	1	4/5	1	1	1	1
a6	1	3/2	1	1	1	1	1	1/2	2
a7	3/7	1	2	2	1	1	1	1	1

The proportion of the scale error caused by the kth expert is c_k. The calculation formula of c_k is as follows:

$$c_k = \left[\frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left(a_{ij}^{k} - a_{ij}^{*} \right)^2}{\sum_{k=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} \left(a_{ij}^{k} - a_{ij}^{*} \right)^2} \right]^{\frac{1}{2}}$$

$$(i, j = 1, 2, \ldots, n,\ k = 1, 2, \ldots, m)$$

Then, the relative weight of the expert can be calculated by the following publicity:

$$\lambda_k = \frac{\frac{1}{c_k}}{\sum_{i=1}^{m} \frac{1}{c_k}} (k = 1, 2, \ldots, m)$$

Through the weight calculation of the seven experts: the scale error ratio and relative weight of the seven experts are (0.230,0.186), (0.309,0.138), (0.202,0.211), (0.672,0.064), (0.267,0.160), (0.290,0.147), (0.452,0.094).

Table 2. The weights of the evaluation index system of students' classroom learning activities.

	Primary Dimension	**Secondary Dimension**	**Tertiary Dimension**
Evaluation Context (1)	Silent situation (0.2796)	Invalid silent situation(0.1216)	Distracted(0.0330)
			Sleep(0.0404)
			Using a mobile phone(0.0482)
		Valid silent situation(0.1580)	Thinking(0.0463)
			Listening(0.0403)
			Taking notes(0.0328)
			Searching for information(0.0386)
	Sound situation (0.2265)	Invalid audio situation (0.0905)	Small talk (0.0518)
			Off-topic group discussion (0.0387)
		Valid audio situation (0.1360)	Active inquiry (0.0513)
			Response (0.0388)
			Participate in discussion (0.0459)
	Attendance (0.1801)	Invalid attendance (0.0772)	late arrival (0.0386)
			early departure (0.0386)
		Valid attendance (0.1029)	on-time attendance (0.0525)
			on-time dismissal (0.0504)
	Homework situation (0.3138)	Invalid homework (0.1349)	plagiarism (0.0738)
			off-topic (0.0611)
		Valid homework (0.1789)	homework quality (0.0965)
			submission time (0.0824)

3.5 Determine the Weight of Evaluation Index System

Combining the different weights of different experts, the geometric average weighting method is used to calculate the weight value of each index. The specific weight values are shown in Table 2.

3.6 Weighted Calculation of Learning Evaluation Effect

For the z1–z20 index, the weight value is set to w_i, and the evaluation score is g_i. Then the final score of the students is:

$$G = \sum_{j=1}^{n} (w_i * g_i)$$

Among them, $n = 20$.

4 Conclusions

This paper aims to explore how to design an effective evaluation index system of learning activities in smart classroom. Specifically, this paper introduces the concepts related to multimodal analysis, and puts forward the principles and methods of index system design, including objectivity, scientificity, integrity, guidance, development and measurability. On this basis, this paper calculates the evaluation weight of learning activities in smart classroom, and finally obtains a complete index system. This index system is not only applicable to smart classrooms, but also can be applied to other teaching projects, and has certain guiding significance. However, in practical application, it is necessary to adjust flexibly according to the specific situation to achieve effective learning analysis. In general, this paper makes a detailed and systematic discussion and analysis on the design of the evaluation index system of smart classroom learning activities, which has certain reference value for researchers, teachers and students of related disciplines.

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