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Online Teaching Quality Evaluation Based on Multi-level Fuzzy Evaluation Method

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Abstract

With the rapid development of Internet information technology, online teaching has become the new normal behavior of school teaching. In order to ensure and improve the quality of online teaching, we comprehensively analyze the elements of various dimensions of online teaching, and establish an index system from three dimensions of teacher teaching, student learning and online resources. The teaching quality evaluation model determines the corresponding evaluation level according to the maximum membership degree of the fuzzy evaluation vector. The results show that the evaluation method can comprehensively consider various factors affecting online teaching, and the evaluation results are objective and reliable.

Keywords: Online teaching, analytic hierarchy process, fuzzy evaluation, teaching quality

1. Introduction

The accelerated evolution of internet-based information technology has had a profound impact on the manner in which individuals engage in both their personal and professional lives, as well as the methods through which they acquire knowledge. In the field of education, the extensive utilization of online platforms and digital tools has rendered online teaching progressively more convenient and efficacious. As technology advances and educational concepts evolve, online teaching can more effectively address the needs of learners and fully realize the value of education. For institutions of higher education, online teaching represents not only a novel pedagogical approach but also a significant component of their regular instructional activities. In this context, prominent universities are proactively promoting and implementing online lectures and learning activities with the objective of enhancing the efficiency and quality of teaching through the utilization of Internet technology. The most significant advantage of online education is its capacity to readily transcend the conventional constraints of time and space. The Internet provides a platform for teachers and students to engage in teaching and learning activities at any time and from any location, thereby eliminating the need for physical movement[1-3]. This flexibility permits the broader distribution and utilization of educational resources, as well as the provision of equal learning opportunities for students who are geographically remote or inconveniently located. Concurrently, the advent of online teaching has enabled the conceptualization of the classroom to extend beyond the traditional physical boundaries, with the advent of virtual classrooms, webinars, online laboratories, and other such innovations.

As the popularity of online teaching formats continues to grow, there is a corresponding increase in scrutiny of the quality of such formats. Schools, teachers, students, and parents have begun to direct their attention toward the quality of the content being taught and the effectiveness of the teaching methods employed by online education platforms[4-6]. The efficacy of online teaching is contingent upon a number of factors, including the appeal of the online teaching resources to students, the ability of teachers to effectively manage the online classroom, and the level of student engagement in online learning. To ensure the continued enhancement of online teaching quality, it is essential to conduct a thorough evaluation of the factors influencing teaching quality and implement targeted improvement strategies[7-10]. These elements include, but are not limited to, the quality of the course content, the practicality of the interactive platform, the online teaching ability of the instructors, and the motivation and engagement of the students. A comprehensive evaluation of these elements allows for a more accurate understanding of the current state of online teaching, the identification of shortcomings, and the development of targeted improvement strategies.

The quality of online teaching has a direct impact on the future of education, as it is a key factor in determining the effectiveness of this educational innovation. The implementation of scientific assessment methodologies to direct and refine online pedagogical practices represents a pivotal strategy for enhancing the quality of education and advancing educational equity. In accordance with the aforementioned, this paper employs a multilevel fuzzy assessment methodology to provide a scientific and objective evaluation of the quality of online teaching. This method provides a quantitative scoring system and a qualitative analysis of the quality of online teaching. This is achieved by developing an index system comprising multiple evaluation levels and employing fuzzy mathematical theory to address the inherent uncertainty inherent in the evaluation process. This enables a comprehensive examination of the numerous factors that exert influence. This approach allows for a comprehensive understanding of the impact of online teaching on a macro level, while also facilitating the formulation of targeted recommendations for enhancing specific aspects of the teaching process. Such measures may include fostering stronger online interaction, optimizing the content of the teaching materials, and improving the user experience of the platform. The objective is to pursue continuous enhancement of the overall quality of online teaching, ensuring that it aligns with the evolving needs of modern education.

2. Methods

The multi-level fuzzy assessment method, which integrates the fuzzy comprehensive evaluation method and the hierarchical analysis method, not only enhances the precision of the assessment but also streamlines the assessment process, rendering it more operational and practical. This method is frequently utilized in the assessment of complex systems comprising multiple levels and a multitude of evaluation criteria. The method initially employs hierarchical analysis to meticulously delineate and ascertain the set of factors, thereby rendering the assessment process more scientific and reasonable. Subsequently, the fuzzy comprehensive assessment method is employed to evaluate the importance of each factor and its impact on the final evaluation results, thereby ensuring the high reliability and accuracy of the evaluation results. The implementation of the hierarchical analysis process typically necessitates adherence to a series of fundamental steps, which can be broadly classified into five principal categories[11-14].

1) Construct a hierarchical structure model. This step serves as the foundation for the entire assessment process. This involves the process of hierarchizing the assessment objectives, assessment objects, and related factors in accordance with specific logical relationships, with the objective of creating a coherent hierarchical structure.

2) Construct a judgment matrix. It is of the utmost importance to construct a judgment matrix that reflects the interrelationships between the factors within the hierarchical structure model during this phase. This is achieved through the implementation of a specific scaling methodology, which serves to facilitate the subsequent calculation of weights.

3) Calculate the weights of the evaluation indices. This phase is based on the judgment matrix, whereby the eigenvalues and eigenvectors are solved to obtain the weight of each evaluation index, thereby reflecting its importance within the overarching evaluation system.

4) The subsequent step is to establish the judgment set and construct the fuzzy matrix of indicator judgments. It is of paramount importance to elucidate the interrelationship between the evaluation indicators and the rubrics in this phase. This necessitates the establishment of the rubrics corresponding to each evaluation indicator as fuzzy, thereby forming a fuzzy matrix of indicator rubrics.

5) Comprehensive assessment results. The weights of the evaluation indicators are multiplied by the fuzzy matrix of the indicator rubrics, thereby obtaining the comprehensive evaluation results. This allows for a quantitative description of the overall performance of the evaluation object.

Following comprehensive research and detailed analysis, and incorporating the valuable insights and feedback from numerous frontline educators, teaching administrators, and students with extensive experience in online education, a set of assessment indicators with a notable impact on the quality of online teaching were identified. In order to establish a hierarchical structure for the assessment indicators, the strength of influence and the closeness of association between the indicators were considered in order to determine their relative importance. This resulted in the construction of a multilevel, systematic assessment model, which is illustrated in Figure 1[15-19]. The model categorizes the assessment indicators in accordance with their interrelationships and their impact on the overall quality of teaching. This hierarchical approach allows for a more precise understanding and assessment of the distinct influence of the various indicators on the quality of online teaching. The assessment model encompasses the fundamental elements of online teaching and learning, with the overarching teaching quality indicators situated at the pinnacle, and three principal dimensions of teacher pedagogy, student learning, and online resources situated in the middle. Each dimension is further delineated by the inclusion of more specific subindicators, which are defined in Figure 1.

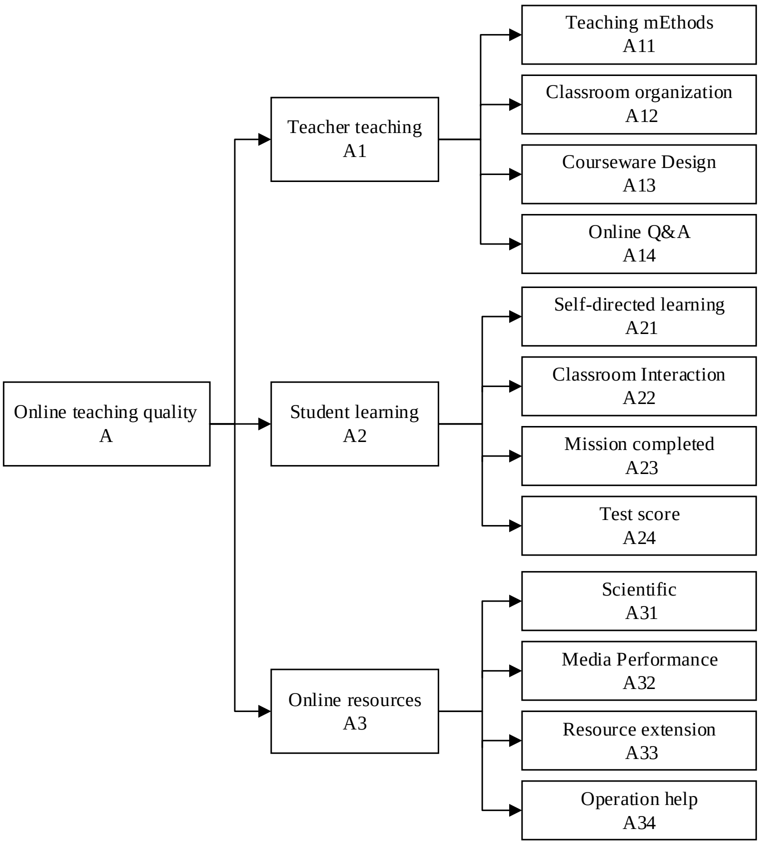

Figure 1 Indicators of the evaluation for online teaching quality

3. Results

3.1 Construct the index judgment matrix

Use " $3^{\frac{n-1}{4}}$ (n=1,2 , 3....9) scaling method " to compare the indicators of the same layer with each other [20],and construct the judgment matrix $A=(a_{ij})_{n\times n}$. a_{ij} in the matrix represents the importance of a_i compared to aj. , $a_{ji}=1/a_{ij}$. When n=1 , 3, 5, 7, 9 , the values of $3^{\frac{n-1}{4}}$ indicates that the pairwise comparison is equally important, relatively important, important, very important and extremely important. When n is another number between 1 and 9, the degree of importance is in the between the corresponding two numbers.

The construction of the judgment matrix is determined by the expert scores. Because the expert scores are subjective, the constructed judgment matrix is difficult to meet the requirements of consistency. In order to ensure the consistency of the judgment matrix, it is converted into a consistency matrix through mathematical operations. When $b_{ij} = \ln a_{ij}$,the judgment matrix A is transformed into an antisymmetric matrix B, when $c_{ij} = \frac{1}{n}\sum_{k=1}^{n}(b_{ik} - b_{jk})$,the transfer matrix C is constructed, and when $A^* = (e^{c_{ij}})_{n\times n}$,the consistency judgment matrix is constructed. The judgment matrices obtained from the expert scores and the transformed consensus matrices are shown in Tables 1~4.

Table 1 Index judgment matrix of online teaching quality (A)

A	**A1**	**A2**	**A3**
A1	1	$3^{\frac{1}{2}}$	3^2
A2	$1/3^{\frac{1}{2}}$	1	3
A3	$1/3^2$	$1/3$	1

Initial judgment matrix

computation $\Rightarrow$

A *	**A1**	**A2**	**A3**
A1	1	2.080	7.494
A2	0.481	1	3.603
A3	0.133	0.278	1

Consistency judgment matrix

Table 2 Index judgment matrix of teacher teaching (A1)

A1	**A11**	**A12**	**A13**	**A14**
A11	1	$3^{\frac{1}{4}}$	3	3^2
A12	$1/3^{\frac{1}{4}}$	1	$3^{\frac{1}{2}}$	$3^{\frac{3}{2}}$
A13	$1/3$	$1/3^{\frac{1}{2}}$	1	$3^{\frac{1}{2}}$
A14	$1/3^2$	$1/3^{\frac{3}{2}}$	$1/3^{\frac{1}{2}}$	1

Initial judgment matrix

computation $\Rightarrow$

A1 *	**A11**	**A12**	**A13**	**A14**
A11	1	1.510	3.213	7.325
A12	0.662	1	2.128	4.851
A13	0.311	0.470	1	2.280
A14	0.137	0.206	0.439	1

Consistency judgment matrix

Table 3 Index judgment matrix of student learning (A2)

A2	**A21**	**A22**	**A23**	**A24**
A21	1	3	$3^{\frac{3}{2}}$	3^2
A22	$1/3$	1	$3^{\frac{1}{2}}$	3
A23	$1/3^{\frac{3}{2}}$	$1/3^{\frac{1}{2}}$	1	$3^{\frac{1}{2}}$
A24	$1/3^2$	$1/3$	$1/3^{\frac{1}{2}}$	1

Initial judgment matrix

computation $\Rightarrow$

A2 *	**A21**	**A22**	**A23**	**A24**
A21	1	3	5.196	9
A22	0.333	1	1.732	3
A23	0.192	0.577	1	1.732
A24	0.111	0.333	0.577	1

Consistency judgment matrix

Table 4 Indicator judgment matrix of Online resource (A3)

A3	A31	A32	A33	A34
A31	1	$3^{\frac{1}{2}}$	$3^{\frac{3}{2}}$	3^{2}
A32	$1/3^{\frac{1}{2}}$	1	$3^{\frac{1}{2}}$	$3^{\frac{3}{2}}$
A33	$1/3^{\frac{3}{2}}$	$1/3^{\frac{1}{2}}$	1	$3^{\frac{1}{2}}$
A34	$1/3^{2}$	$1/3^{\frac{3}{2}}$	$1/3^{\frac{1}{2}}$	1

Initial judgment matrix

computation $\Longrightarrow$

A3 *	A31	A32	A33	A34
A31	1	1.987	4.529	9
A32	0.503	1	2.280	4.529
A33	0.221	0.439	1	1.987
A34	0.111	0.221	0.503	1

Consistency judgment matrix

3.2 Calculate the weight of the evaluation index

The multilevel fuzzy assessment method guarantees the rationality and scientificity of the assigned weights for the evaluation indicators by solving the eigenvector of A* for the corresponding consistent judgment matrix[12-16]. This enables the weights for each evaluation indicator to be determined, transforming subjective judgments by experts into objective weight values through the use of mathematical models. This provides a quantitative basis for decision-making and ensures the rationality and scientificity of the assigned weights for the evaluation indicators.

The weight of the evaluation index is equal to the eigenvector W of the corresponding consistent judgment matrix A*, which can be calculated using the formula provided in Equation (1). The weight vector of each layer index is presented in Equations (2) through (5).

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}^*}{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}^*} (i, j = 1,2...n) \tag{1}$$

$$\mathrm{W_A} = (0.6195,0.2978,0.0827) \tag{2}$$

$$\mathrm{W_{A1}} = (0.4739,0.3139,0.1475,0.0647) \tag{3}$$

$$\mathrm{W_{A2}} = (0.6109,0.2036,0.1176,0.0679) \tag{4}$$

$$\mathrm{W_{A3}} = (0.5449,0.2742,0.1203,0.0606) \tag{5}$$

3.3 Construct the index score fuzzy matrix

In order to evaluate the quality of online teaching, a four-point grading system was devised. The grades A, B, C, and D are consistent with the rubrics set V = (A, B, C, D). In order to mitigate the impact of subjective perceptions and ambiguity in the expert rating process, a trapezoidal curve is employed to construct the grade affiliation function, as illustrated in Figure 2. This approach is capable of fuzzing the rating scale and then forming an indicator fuzzy matrix R [13,14,16], which is capable of capturing the nuances of the evaluation. As a result of this methodology, the resulting evaluations are rendered more objective and scientific in nature.

In the specific implementation process, experts were invited to score the courses of the three online teaching instructors, and the specific scoring data are recorded in Table 5 for analysis. The previously designed rank affiliation function was employed to construct the scoring fuzzy matrix of the lowest evaluation index for online teaching quality, as illustrated in Table 6. The matrix illustrates both the experts' evaluation of teaching quality and the process of fuzzification of the aforementioned evaluation results through the aforementioned affiliation function. This approach permits a more nuanced and comprehensive assessment of online teaching quality.

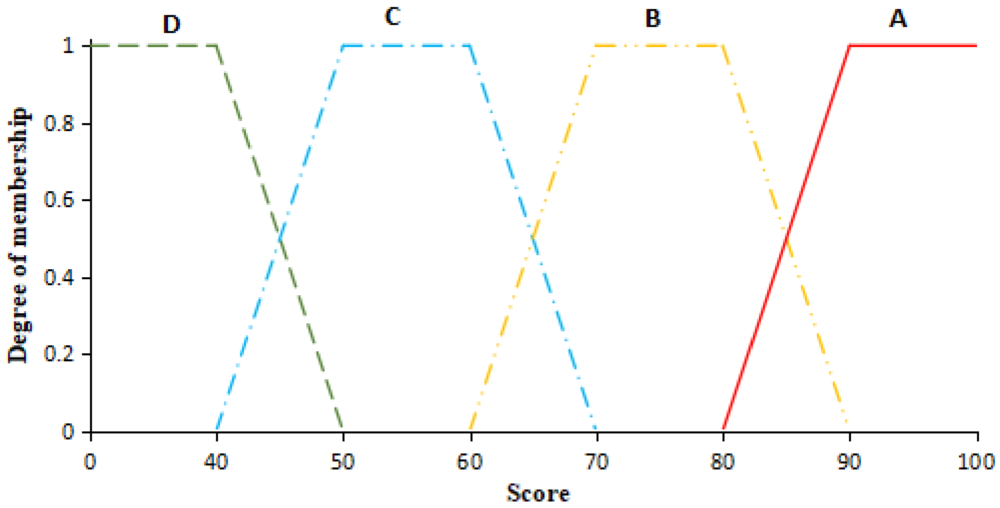

Figure 2 Level membership function

Table 5 Score sheet of online quality teaching

Evaluation indicators		Online teaching I	Online teaching II	Online teaching III
Teacher teaching A1	teaching method A11	66	39	78
	Classroom Organization A12	38	57	61
	Courseware Design A13	39	71	79
	Online Q&A A14	41	68	79
Student learning A2	Self-learning A21	87	82	54
	class interaction A22	36	50	80
	mission completed A23	90	79	68
	test scores A24	64	41	77
Online resources A3	scientific A31	76	88	71
	media performance A32	44	67	74
	Resource extension A33	58	90	38
	Operation help A34	94	69	56

Table 6 Index score fuzzy matrix R

Evaluation indicators		Evaluation level											
		Online teaching I				Online teaching II				Online teaching III			
		A	B	C	D	A	B	C	D	A	B	C	D
A1	A11	0	0.6	0.4	0	0	0	0	1	0	1	0	0
	A12	0	0	0	1	0	0	1	0	0	0.1	0.9	0
	A13	0	0	0	1	0	1	0	0	0	1	0	0
	A14	0	0	0.1	0.9	0	0.8	0.2	0	0	1	0	0
A2	A21	0.7	0.3	0	0	0.2	0.8	0	0	0	0	1	0
	A22	0	0	0	1	0	0	1	0	0	1	0	0
	A23	1	0	0	0	0	1	0	0	0	0.8	0.2	0
	A24	0	0.4	0.6	0	0	0	0.1	0.9	0	1	0	0
A3	A31	0	1	0	0	0.8	0.2	0	0	0	1	0	0
	A32	0	0	0.4	0.6	0	0.7	0.3	0	0	1	0	0
	A33	0	0	1	0	1	0	0	0	0	0	0	1
	A34	1	0	0	0	0	0.9	0.1	0	0	0	1	0

3.4 Fuzzy evaluation of online teaching quality

The element r_{ij} of the fuzzy matrix R represents the degree of membership of the i-th index on the j-th evaluation level. It is multiplied by the index weight W of the same layer to obtain the evaluation fuzzy vector of the index of the previous layer. The fuzzy evaluation vector of online teaching quality can be obtained by transferring it up layer by layer. The fuzzy comprehensive evaluation formula is shown in Equation (6). From this announcement, the evaluation fuzzy vectors of the indexes of the second layer and the first layer can be calculated. According to the maximum membership degree of the fuzzy evaluation results, the evaluation level of online teaching quality can be determined, and at the same time, the quality of online teaching can be further analyzed according to the degree of membership of each level (4).

$$\mathrm{V} = \mathrm{W} \times \mathrm{R} = (\sum_{i=1}^{n} w_i r_{i1}, \sum_{i=1}^{n} w_i r_{i2}, \ldots, \sum_{i=1}^{n} w_i r_{in}) \tag{6}$$

Substituting the evaluation index weights of each layer of online teaching I and the fuzzy scoring matrix of the same layer into formula (1), we can get the fuzzy vector of scoring of each layer of online teaching I as follows:

$$^{1}\mathrm{V}_{\mathrm{A1}} = \mathrm{W}_{\mathrm{A1}} \times {}^{1}\mathrm{R}_{\mathrm{A1}} = (0.0000, 0.2843, 0.1961, 0.5196) \tag{7}$$

$$^{1}\mathrm{V}_{\mathrm{A2}} = \mathrm{W}_{\mathrm{A2}} \times {}^{1}\mathrm{R}_{\mathrm{A2}} = (0.5452, 0.2104, 0.0408, 0.2036) \tag{8}$$

$$^{1}\mathrm{V}_{\mathrm{A3}} = \mathrm{W}_{\mathrm{A3}} \times {}^{1}\mathrm{R}_{\mathrm{A3}} = (0.0606, 0.5449, 0.2300, 0.1645) \tag{9}$$

$$^{1}\mathrm{V}_{\mathrm{A}} = \mathrm{W}_{\mathrm{A}} \times {}^{1}\mathrm{R}_{\mathrm{A}} = \mathrm{W}_{A} \times \begin{pmatrix} ^{1}V_{A1} \\ ^{1}V_{A2} \\ ^{1}V_{A3} \end{pmatrix} = (0.1674, 0.2839, 0.1526, 0.3961) \tag{10}$$

In the same way, the fuzzy vectors of ratings for online teaching II and III are:

$$^{2}\mathrm{V}_{\mathrm{A}} = (0.0824, 0.3334, 0.2724, 0.3118) \tag{11}$$

$$^{3}\mathrm{V}_{\mathrm{A}} = (0.0000, 0.6211, 0.3690, 0.0099) \tag{12}$$

According to the maximum membership degree of the evaluation grade, it can be seen that the quality grade of online teaching I is grade D, the teaching quality grade of online teaching II and III is grade B, but the degree of online teaching III belonging to grade B is greater than that of online teaching II. At the same time, the second largest membership degree of online teaching III corresponds to grade C, and the second largest membership degree of online teaching II corresponds to grade D. This shows that further detailed analysis can be obtained: the quality of online teaching III with grade B is better than that of online teaching II.

4. Discussion

There are many online teaching quality evaluation indexes. Based on the suggestions of many teachers, teaching supervisors and students, this paper evaluates and classifies the online teaching quality from 12 indexes in three dimensions: teacher teaching, student learning and online resources. In order to reduce the influence of the subjectivity and fuzziness of the evaluators, a multi-level fuzzy evaluation method is introduced to evaluate the online teaching quality level according to the maximum membership degree of the evaluation level. The evaluation results are objective.

How to quantify qualitative judgment when constructing the judgment segment matrix by the analytic hierarchy process? The “1-9 judgment scale” method proposed by T.L. Saaty is usually used, but this method is not consistent with the actual scale system in people's minds. This paper uses the” $3^{\frac{n-1}{4}}$ (n=1,2,3....9) scale” method to construct the judgment segment matrix, which has been proved to be more consistency and compatibility than the “1-9 judgment scale” method [20].

In the process of constructing the judgment matrix, no matter what scale method is used, it is impossible for evaluators to accurately judge the values of all factors, and there will certainly be errors. If the constructed judgment matrix cannot meet the requirements of consistency, subsequent evaluation will not be possible. In this paper, the initial judgment matrix is converted into a consistency matrix through conversion matrix, which naturally meets the requirements of consistency test.

Fuzzy comprehensive evaluation is a very effective multifactor decision-making method to comprehensively evaluate things affected by many factors. Its characteristic is that the evaluation results are not absolutely positive or negative, but represented by a fuzzy set. Applying the fuzzy evaluation method to online teaching quality evaluation can comprehensively consider many factors that affect online teaching. According to the importance of each factor and its evaluation results, the original qualitative evaluation can be quantified to better deal with the multiple factors, fuzziness and subjective judgment of online teaching.

In practical application, the teaching of engineering courses, science courses and liberal arts courses has their own different emphases, and the teaching characteristics of theoretical courses and practical courses are also different. It is suggested to further refine and increase the relevant indicators of different dimensions in combination with the characteristics of specific online teaching courses, so as to make the multi-level evaluation model system more reasonable and the evaluation results more instructive for different types of online teaching courses.

5. Conclusions

The findings of the study demonstrate that this assessment system considers and incorporates the primary factors influencing the diversity and intricacy of online teaching in a comprehensive manner. The findings of the study provide substantial guidance for educators engaged in online instruction, students engaged in online learning, the administration of distance education, and the advancement and optimization of online teaching resources. It can assist relevant educators and researchers in gaining a more profound understanding of the multifaceted aspects of online teaching, thereby ensuring the enhancement of online teaching quality and learning outcomes, fostering the advancement of teaching methods and technologies, and contributing to the development of a more efficient, interactive, and personalized online teaching environment.

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