Research on the Multilevel Indicator Evaluation Model of Online Learning Based on Fuzzy Set

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Abstract Learning evaluation is an effective way to ensure the quality of online education. However, most of online learning evaluation models are not fully consider the characteristics of online learning. This paper, from the view of the characteristics of online learning, establishes an index system of evaluation of the online learning's effect. Besides, weight of every factor affecting online learning is calculated by using entropy method. At the same time, a model based on entropy weight of the fuzzy comprehensive evaluation is established and its calculation is given out. At last, the learning effects of a learner are evaluated and its result is analyzed by this model.
Key words Entropy; Online learning; Weight; Fuzzy Comprehensive evaluation

1 Introduction

Learning for a long life is the current development trend of social education. Construction of modern network education is the primary means of lifelong learning system. Internet offers an ideal learning environment for distance education. With the launch of online learning, its' quality has aroused extensive concern. Quality of online education is the key to development for online learning, and also the core competence for the long-term development of online education. Learning evaluation is effective way to ensure the quality of online education. Learning evaluation is also the core of online education evaluation system.

Currently, the evaluation of online learning is concerned by domestic and foreign scholars. For example, Ellen.B researched the development trend of learning evaluation [1]. Jconghee Huh had researched the evaluation about reading activities in e-learning [2]. Moreover, the evaluation of online learning was used in online education by some countries. Meanwhile, the development of online learning evaluation system also been researched. These studies mainly focus on the design and implementation of online learning evaluation system. Some universities have developed these systems. Such as Web-CT, WISH, Virtual-U, Black-Board, Course-Info, Path-Ware [3]. However, most of these studies used the traditional education and learning evaluation system to evaluate the online learning. In traditional education and learning evaluation system, written or online tests are the main forms of evaluation, learning evaluation was made by teachers, learners' level were often measured by learners' test results. It can not fully consider the characteristics of online learning. It was difficult to adapt to rapid development of online learning. Therefore, it needs to establish new indicators evaluation system to adapt to the feature of online learning.

2 Evaluation Indicator System of Online Learning

Learning behavior was a multi-dimensional and multi-level learning style, which was carried out by means of the Internet; it was a behavior of student self-discipline and self-control. Actors had sufficient autonomy to determine learning goals, learning schedule, learning strategies, learning resources, as well as the occurrence and changes of the learning behavior. We could describe the learning behavior by the following model .

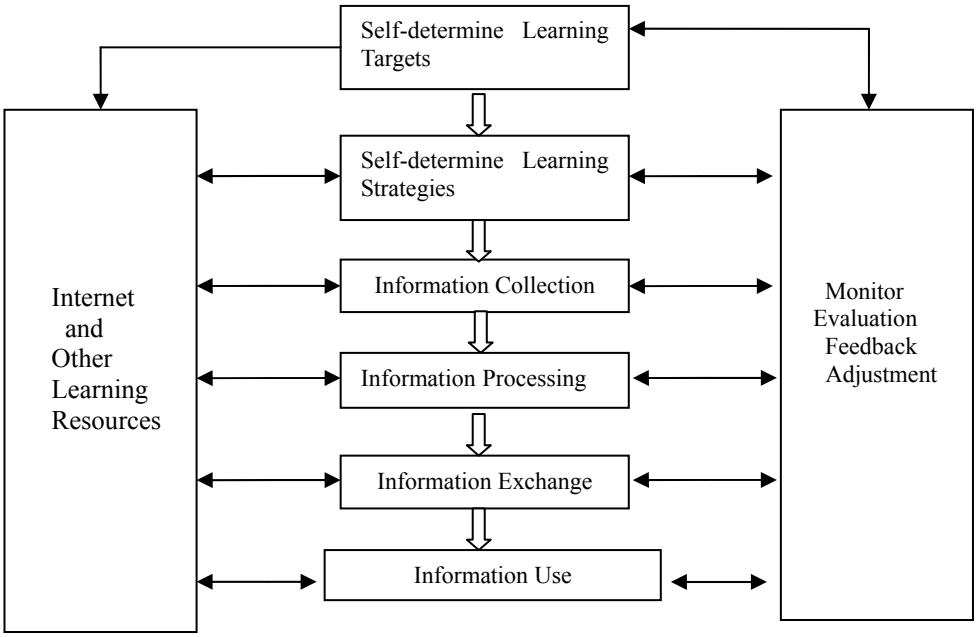

Figure 1 Behavior Model of Online Learning

Through this model, we could summarize the main internal factors that have impact on online learning such as preparation for learning, attitude of learning, learning ability of learners and information exchange capabilities. In addition to internal factors, the contents of online course and online test also affected the evaluation of online learning behavior. We summarized these factors as external factors which were impact of online learning. Therefore, evaluation indicator system of online learning could be divided into 6 first grade indicators and 27 second grade indicators.

3 Online Learning Assessment Model Based on Entropy Weight Fuzzy Comprehensive Evaluation Method

3.1 The model of entropy calculation

In the online learning assessment,different indicators will have different impacts on the effect of online learning . Therefore, we need to assign weight to every indicator. In the traditional method, we directly assign every indicator's weight by experience. This method is very simple, but is difficult to be objective and reasonable. Meanwhile, it is difficult to ensure consistency in the process of critical thinking. In this paper, concerning the characteristics of the online learning, we invite several learner's partners and teachers as experts to mark, so as to make the weights to be in line with the actual situation. However, different evaluators have different understanding to the factors which impact on the effect of online learning, because of different background, therefore, weight has some divergence. In order to get the weight of reflecting objective requirements on the subjective evaluation basis, we use method of entropy assessment to analyze and process the result objectively. In other words, it is to calculate the weight of every indicator relative to the weight of upper indicators through the inner relations among those indicators. In this method, subjective judgment is combined with objective calculation. And the calculation is as following [5].

There are *m* evaluators and *n* indicators. y_{ij} .is the score from evaluator *i* evaluate indicator *j*. Then:

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots\cdots & y_{1n} \\ y_{21} & y_{22} & \cdots\cdots & y_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ y_{m1} & y_{m2} & \cdots\cdots & y_{mn} \end{bmatrix}, y_j^* \text{ is the highest score of indicator } j. \text{ It is the value which}$$

reflects the effect of assessing every indicator. d_{ij} is the approaching degree between y_{ij} and y_j^* ,

then

$$d_{ij} = y_{ij} / y_j^* \tag{1}$$

According to the definition of entropy, H is the entropy of m evaluators and n indexes.

$$H = -\sum_{j=1}^{n}\sum_{i=1}^{m} d_{ij} \ln d_{ij} \tag{2}$$

Table 1 Evaluation Indicator System of Online Learning

Preparation for learning U_1	Basic knowledge of discipline U_{11}
	The convenience of learning time U_{12}
	Plan of learning U_{13}
	Computer ability of learners U_{14}
	The economic situation of learners U_{15}
Attitude of learning U_2	Participate in online teaching and learning activities actively U_{21}
	Study on Internet by self U_{22}
	Without cheating in the online test U_{23}
	Submitting the work timely U_{24}
Ability of Learning U_3	Using Internet search tools U_{31}
	Using online database resources U_{32}
	Using forum resources U_{33}
	Using multimedia resources U_{34}
	Answer questions on the Web U_{35}
Information exchange capabilities U_4	Published the views of relevant courses in the forum U_{41}
	Discuss experiences with other partners in the forum U_{42}
	Giving the suggestion on the online teaching U_{43}
	completing the relevant issues with other learning partners U_{44}
Contents of online course U_5	The correlation of knowledge U_{51}
	The continuity of knowledge modules U_{52}
	The scalability of knowledge U_{53}
	The integrity of knowledge U_{54}
	The stability of knowledge structure U_{55}
Contents of online test U_6	The difficulty of online tests U_{61}
	The knowledge coverage of online test U_{62}
	Amount of test questions U_{63}
	The knowledge extension of the online test U_{64}

The uncertainty of the index is decided by the conditional entropy H'

$$H' = -\sum_{i=1}^{m} (d_{ij} / d_j) \ln(d_{ij} / d_j), d_j = \sum_{i=1}^{m} d_{ij} \tag{3}$$

$H'_{\max} = \ln m$, conditional entropy is normalized by $H'_{\max}$, $e(d_j)$ is the entropy which reflects the importance of indicator.

$$e(d_j) = H^{'} / \ln m \tag{4}$$

W_j is the weight of index. $w_j = [1 - e(d_j)] / \sum_{j=1}^{n} [1 - e(d_j)]$ (5)

3.2 Constructing model based on entropy weight fuzzy comprehensive evaluation

3.2.1Constructing a set of evaluation factors

According to the properties of the evaluation factors, a set U can be established. In this paper, *U* contains 6 first grade indicators as: $U = \{U_1, U_2, ..., U_6\}$. Every first grade indicator contains several second grade indicators as: $U_i = \{U_{i1}, U_{i2}, ..., U_{ij}, ..., U_{ik}\}, (j = 1,2...., k)$

Reviews of each index are divided into *m* levels. In this paper, 5 grade reviews are used to evaluate every indicator of the model. $V = \{V_1, V_2, V_3, V_4, V_5\}$. *V* is a set of reviews. In the set V_1 is the worst, the score of V_1 is between 0 and 20. V_2 is worse, its score is between 20 and 40. V_3 is normal , its score is between 40 and 60 . V_4 is better , its score is between 60 and 80 . V_5 is the best, its score is between 80 and 100 . Those 'best', 'better' , 'normal' , 'worse' , 'worst' represent the effect of the online learning[6] .

3.2.2 Determining the weight of every indicator

The weight of the index of first level is calculated by the model of entropy calculation. *W* is a set of weight as $W = \{W_1, W_2, W_3, W_4, W_5, W_6\}$. W_i is a set of sub-indicator , $W_i = \{W_{i1}, W_{i2}, .., W_{ik}\}$. Process of calculation is in Section 3.1.

3.2.3 Constructing evaluation matrix

R_j is the fuzz matrix from U_{ij} to *V.*

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & ..... & r_{i15} \\ r_{i21} & r_{i22} & ..... & r_{i25} \\ ... & ... & ... & ... \\ r_{ik1} & r_{ik2} & ..... & r_{ik5} \end{bmatrix}$$

In this paper, r_{ijp} is the membership grade of U_{ij} to V_p, V_p is element of *V*. According to the statistics of the experts' scores , we can get U_{ij}, there are m_{ij1} reviews belonged to V_1, m_{ij2} reviews belonged to V_2, m_{ij3} reviews belonged to V_3, m_{ij4} reviews belonged to V_4, m_{ij5} reviews belonged to V_5 , at last , we can obtain the value of r_{ijp}.

$$r_{ijp} = m_{ijp} / \sum_{p=1}^{5} m_{ijp} \tag{6}$$

3.2.4 Calculating the value of model

Calculating R_i with fuzzy method C_i is obtained. C_i is the vector , which reflects the membership grade of U_i to *V.*

$C_i = W_i \bullet R_i$. $C_i = (C_{i1}, C_{i2}, C_{i3}, C_{i4}, C_{i5})$, $C_{ip} = \min\{1, \sum_{j=1}^{k} W_{ij} r_{ijp}\}$ (*p*=1,2,…5) (7)

Judgment matrix *R* is composed with all the vectors C_i.

$$R=\begin{bmatrix} C_1 \\ C_2 \\ .... \\ C_6 \end{bmatrix}=\begin{bmatrix} C_{11} & C_{12} & ... & C_{15} \\ C_{21} & C_{22} & ... & C_{25} \\ ... & ... & ... & ... \\ C_{61} & C_{62} & ... & C_{65} \end{bmatrix} \tag{8}$$

$$C=W \bullet R=(W_1,W_2,...,W_6) \bullet (C_1,C_2,...,C_6)^T=(\bar{c}_1,\bar{c}_2,...,\bar{c}_5) \tag{9}$$

$\bar{c}_p$ =min $\{1,\sum_{i=1}^{6} W_i C_{ip}\}$ (p=1,2,..,5) when $\sum_{p=1}^{5} \bar{c}_p \neq 1$, normalized *C*,

s.t. $\sum_{p=1}^{5} \bar{c}_p = 1, \hat{c}_p = \bar{c}_p / \sum_{p=1}^{5} \bar{c}_p$

At last, $u=90\times\bar{c}_1+70\times\bar{c}_2+50\times\bar{c}_3+30\times\bar{c}_4+10\times\bar{c}_5$, u is the result of model , the bigger the value of u is , the better the effect of the online learning is .

4 Case Studies

Now there is an online learner, 6 experts evaluate the effect of online learning. They score all the indicators from different levels and the indicators are presented in Table 1.The range of score is 1 to 10. *Y* is the score of the relative importance of fist-level indicators.Y_1, Y_2, Y_3, Y_4, Y_5, Y_6 is the score of the relative importance of second-level indicators which belong every fist-level indicators.

$$Y=\begin{bmatrix} 5 & 9 & 8 & 5 & 6 & 8 \\ 5 & 8 & 6 & 7 & 7 & 6 \\ 5 & 6 & 5 & 6 & 7 & 5 \\ 4 & 7 & 7 & 5 & 6 & 6 \\ 5 & 6 & 6 & 5 & 7 & 6 \\ 4 & 9 & 9 & 7 & 8 & 7 \end{bmatrix} \quad Y_1=\begin{bmatrix} 5 & 8 & 5 & 5 & 6 \\ 7 & 6 & 4 & 6 & 5 \\ 6 & 7 & 5 & 6 & 7 \\ 7 & 7 & 5 & 5 & 5 \\ 8 & 6 & 6 & 5 & 6 \\ 5 & 5 & 5 & 4 & 6 \end{bmatrix} \quad Y_2=\begin{bmatrix} 6 & 8 & 7 & 6 \\ 7 & 6 & 8 & 6 \\ 6 & 7 & 7 & 5 \\ 7 & 9 & 9 & 5 \\ 8 & 6 & 8 & 7 \\ 6 & 5 & 7 & 8 \end{bmatrix}$$

$$Y_3=\begin{bmatrix} 5 & 7 & 7 & 6 & 4 \\ 5 & 9 & 7 & 6 & 4 \\ 6 & 8 & 5 & 5 & 4 \\ 5 & 6 & 6 & 5 & 5 \\ 7 & 7 & 5 & 7 & 5 \\ 5 & 8 & 6 & 5 & 4 \end{bmatrix} \quad Y_4=\begin{bmatrix} 5 & 7 & 7 & 6 \\ 5 & 6 & 8 & 6 \\ 7 & 7 & 5 & 7 \\ 6 & 8 & 7 & 5 \\ 6 & 5 & 6 & 5 \\ 4 & 5 & 6 & 5 \end{bmatrix} \quad Y_5=\begin{bmatrix} 6 & 7 & 7 & 6 & 7 \\ 5 & 6 & 8 & 6 & 6 \\ 8 & 7 & 5 & 7 & 6 \\ 6 & 8 & 7 & 5 & 5 \\ 6 & 5 & 6 & 5 & 7 \\ 7 & 5 & 9 & 5 & 8 \end{bmatrix} \quad Y_6=\begin{bmatrix} 6 & 7 & 7 & 6 \\ 9 & 6 & 8 & 6 \\ 8 & 7 & 6 & 7 \\ 6 & 8 & 7 & 5 \\ 6 & 5 & 6 & 5 \\ 7 & 5 & 5 & 5 \end{bmatrix}$$

According to Formula (1),(3),(5),we can calculate the relative weights of fist-level indicators.*W* is the weight which is from U_i to *U*. $W=\{W_1,W_2,...,W_6\}$ ={0.086,0.232,0.228,0.190,0.083,0.179}.

The same as *W*:

$W_1=\{0.307,0.219,0.155,0.180,0.138\}$, $W_2=\{0.130,0.407,0.151,0.312\}$,

$W_3=\{0.219,0.195,0.247,0.201,0.137\}$ $W_4=\{0.292,0.292,0.255,0.161\}$,

$W_5=\{0.187,0.263,0.217,0.145,0.188\}$, $W_6=\{0.251,0.291,0.297,0.161\}$

The experts score all the 27 indicators referred in Table 1. The range of score is 0 to 100.The score higher the risk higher. From the view of statistics, the result is reasonable. According to Formula (6), the judgment matrixes are obtained.

$$R_1=\begin{bmatrix}0&0.2&0.2&0.3&0.3\\0.1&0.1&0.2&0.3&0.3\\0&0.1&0.2&0.3&0.4\\0&0&0.3&0.4&0.3\\0.2&0.3&0.3&0.1&0.1\end{bmatrix}\quad R_2=\begin{bmatrix}0.1&0.2&0.3&0.3&0.1\\0.2&0.2&0.3&0.2&0.1\\0.1&0.2&0.2&0.2&0.3\\0.1&0.1&0.2&0.3&0.3\end{bmatrix}\quad R_3=\begin{bmatrix}0.2&0.2&0.3&0.2&0.1\\0.1&0.2&0.2&0.3&0.2\\0.1&0.1&0.2&0.3&0.3\\0.1&0.2&0.2&0.3&0.2\\0.1&0.2&0.3&0.3&0.1\end{bmatrix}$$

$$R_4=\begin{bmatrix}0&0.1&0.2&0.3&0.4\\0.1&0.2&0.2&0.3&0.2\\0.1&0.2&0.3&0.3&0.1\\0.1&0.2&0.3&0.2&0.2\end{bmatrix}\quad R_5=\begin{bmatrix}0.1&0.1&0.2&0.3&0.3\\0.1&0.1&0.3&0.3&0.2\\0.1&0.2&0.2&0.3&0.2\\0.1&0.1&0.2&0.2&0.4\\0.1&0.2&0.2&0.3&0.2\end{bmatrix}\quad R_6=\begin{bmatrix}0.1&0.2&0.3&0.3&0.1\\0.1&0.1&0.2&0.3&0.3\\0.1&0.2&0.3&0.2&0.2\\0.1&0.2&0.2&0.3&0.2\end{bmatrix}$$

According to Formula (7), C_1 can be calculated

$$C_1 = W_1 \bullet R_1 = \{0.0495, 0.1402, 0.2316, 0.2901, 0.2876\}$$

The same as C_1, C_2, C_3, C_4, C_5, C_6 also can be calculated. According to Formula (8),

Judgment matrix R can be calculated.

$$R=\begin{bmatrix}C_1\\C_2\\C_3\\C_4\\C_5\\C_6\end{bmatrix}=\begin{bmatrix}0.0495&0.1402&0.2316&0.2901&0.2876\\0.1407&0.1688&0.2537&0.2442&0.1962\\0.1218&0.1751&0.2354&0.2778&0.1889\\0.0708&0.1708&0.2416&0.2839&0.2329\\0.1&0.1217&0.2263&0.2855&0.2477\\0.1&0.1709&0.2548&0.2703&0.204\end{bmatrix}$$

According to Formula (9),

$$C=W \bullet R = (0.1043,0.1643,0.2427,0.271,0.2147)$$

The value of the effect of A's online learning maybe 10.43% between 0 -20,16.43% between 20-40,24.24.27% between 40-60,27.1% between 60-80,21.46% between 80-100.

At last, $u = 10 \times \bar{c}_1 + 30 \times \bar{c}_2 + 50 \times \bar{c}_3 + 70 \times \bar{c}_4 + 90 \times \bar{c}_5$

=0.1043*10+0.1643*30+0.2427*50+0.271*70+0.2147*90=56.391

The value of the effect is 44.036. Therefore, the effect of A's online learning is normal.

5 Conclusions

Evaluation of the online learning is a complicated process. The effect of online learning is influenced of all kinds of factors .While the weight of these factors is determined, we can make a reasonable assessment for the effect of online learning so that learning of students' and teaching methods of teachers' could be adjusted in time . At the same time, an indicator system of online learning assessment is founded. Weight of every factor is calculated by entropy theory. Through the establishment of fuzzy comprehensive evaluation model to evaluate the effect of the online learning, teachers can understand the current status of online learner better, and then teachers can manage the online learning more effectively.

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