

An Evaluation Method for Curriculum Learning Outcomes Achievement Based on Cloud Model under the OBE Concept

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Abstract. Learning outcomes evaluation has been an indispensable important segment in outcomes-based education (OBE), and becoming a significant method to guarantee the quality of education in many countries. The achievement of curriculum learning outcomes should not be judged only on final exam results, but also the added learning value including the students' knowledge, skills, abilities and so on. Moreover, the evaluation results will be of great value for continuous improvement of teaching quality. In this paper, learning outcomes achievement is used as the index to evaluate the students' performance and advancement in the teaching-learning process, and it is quantized signifying by the numerical characteristics of cloud model. Taking the factors, such as learning attitude, craftsmanship spirit, professional knowledge and skills into account, an evaluation model of learning outcomes achievement based on cloud model is proposed. It helps to grasp the teacher's teaching effect and the students' mastery of the curriculum content and professional skills more clearly. An example was given to validate the evaluation model, and the results indicated that the model could realize the transformation of qualitative and quantitative evaluation, and give precise numerical values to represent the students' learning outcomes comprehensively. According to the comparison of the evaluation results, teachers could also discover the problems in teaching and learning, and then took appropriate measures to optimizing the teaching contents, methods and models. As a result, students' learning outcomes were promoted obviously with the improvement.

Keywords: outcomes-based education; cloud model; curriculum learning outcomes; achievement evaluation.

1. Introduction

Since put forward by William G. Spady in 1981, outcomes-based education (OBE), as an advanced education concept, had been quickly accepted and paid attention to by the academia and the industry. It has now been adopted by multiple levels of the education systems around the world. The learning theory of OBE calls for teacher-instructed and student-centered learning. And the curriculum teaching, oriented with students' expected capability acquisition, is reversely designed and positively practiced. The students' learning outcomes are the focus of attention. The concept was first proposed by Eisner, referring to the result obtained by taking part in teaching activities in some form [1]. At present, a lot of domestic and overseas scholars have done in-depth researches on the connotation of learning outcomes, which can be classified into two categories: the expected learning outcomes and the actual achieved learning outcomes, both including knowledge, skill, ability, attitude and so on[2-5]. This study evaluates the students' actual achieved learning outcomes after a learning stage. As learning outcomes can reflect students' learning added value and reveal the teaching effects, the evaluation of students' learning outcomes, as an important segment in OBE, has become a hot issue of the quality evaluation of talent cultivation.

The evaluation of learning outcomes is a dynamic, diverse and complicated process. It is necessary to carry out the whole process follow-up and procedural evaluation, not only to measure the summative assessment, but also the formative assessment. Furthermore, the evaluation under the OBE concept advocates constructing a comprehensive appraisal system with multi-subject, multi-method, multi-index, multi-dimension, and complex content, which is of benefit to evaluate the students' overall development. Therefore, the procedure has the characteristics of complexity,

fuzziness and randomness. Thus far, many efforts have been made to deal with this issue, but the quantitative methods mainly focus on analyzing the final learning outcomes, such as statistical analysis method, data mining method, questionnaire method, index weighting method and so forth [6-14]. They cannot provide immediate judgment and feedback for students' learning state and outcomes in the entire process of learning. And the results have very restricted significance on the real-time adjustment and optimization of classroom teaching. To solve this problem, in this paper, we introduce cloud model theory into the teaching-learning process and build an evaluation model of learning outcomes achievement. In our method, the students' learning outcomes achievement is quantized signifying by the numerical characteristics of cloud model, and multiple qualitative indicators and quantitative indicators are considered all together. By comparing the cloud similarities between classroom learning outcomes achievement and evaluation grades, our method can analyze the students' learning progress in a timely manner and provide reference results for continuously optimizing teaching content, diversifying teaching methods, exploring teaching models and improving teaching effectiveness.

This paper is organized as follows: In section II, cloud model and reverse cloud algorithm are introduced; in section III, the evaluation model of learning outcomes achievement is proposed; in section IV, applications and results are presented; finally, section V gives some conclusions and suggestions for the future works.

2. Cloud Model

Cloud model [15] is a cognitive model first proposed by Prof. Deyi Li, which can realize the conversion of qualitative concept and quantitative concept, and reflect the fuzziness and randomness in linguistic assessment. It has been widely applied in the field of artificial intelligence, data mining, assessment decision, etc. In the cloud model, the numerical characteristics are expressed with Expectation Ex , Entropy En and Hyperentropy He to reflect the qualitative concept C , that is recorded as $C(Ex, En, He)$. Ex is the most representative point of the qualitative concept. En , as the uncertainty measure of the concept, is determined by both the fuzziness and randomness of the concept; and it reflects the dispersion degree of the cloud droplets. He is the second-order entropy of the entropy and co-determined by fuzziness and randomness of Entropy En ; it reflects the extent to which the qualitative concept is generally accepted. The smaller Hyperentropy He is, the more extensively the concept is accepted.

Because of the universality of normal distribution in nature, Gaussian cloud model is adopted in the study. Let U be a universal set described by precise numbers. If $x \in U$, a quantitative value that randomly realizes the concept C , the certainty degree of x for C , i.e. $\mu(x) \in [0,1]$, is defined as the following:

$$\mu(x) = \exp \left[-\frac{(x-Ex)^2}{2(En')^2} \right] \quad (1)$$

Where En' subjects to Gaussian distribution, whose expectation is En , and variance is He^2 . Fig. 1 shows the cloud diagrams with different numerical characteristics. It can be observed that the smaller Entropy En is, the more concentrated the cloud droplets are; the larger Hyperentropy He is, the thicker the cloud shape is.

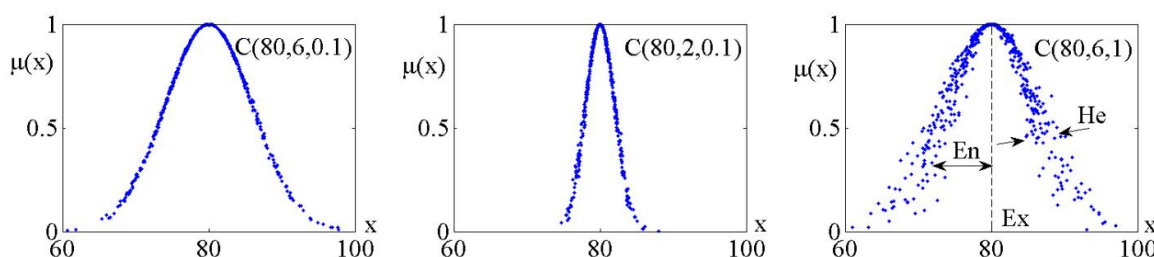


Fig. 1 Cloud diagrams with different numerical characteristics (Ex, En, He)

As the distribution of the certainty degree $\mu(x)$ has nothing to do with the numerical characteristics of the concept C , that is, it has nothing to do with the connotation of the concept, which means that although there are differences in individual cognition of the same concept, the general cognitive rule is consistent. Based on this value of cloud model, it is especially suited for the evaluation of students' learning outcomes achievement under the comprehensive appraisal system.

The reverse Gaussian cloud algorithm can realize the transformation from the students' learning data samples to the numerical characteristics (Ex, En, He) of the qualitative assessment of the learning outcomes achievement. The algorithm is as follows:

Input: Students' learning data samples $x_i, i = 1, 2, \dots, n$.

Output: (Ex, En, He) .

Steps: (1) Calculate the mean \hat{Ex} , variance c_2 and 4-order central moment c_4 .

$$\hat{Ex} = \frac{1}{n} \sum_{i=1}^n x_i \quad (2)$$

$$c_2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \hat{Ex})^2 \quad (3)$$

$$c_4 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \hat{Ex})^4 \quad (4)$$

(2) Calculate the Entropy \hat{En} and Hyperentropy \hat{He} .

$$\hat{En} = \left(\frac{9c_2^2 - c_4}{6} \right)^{1/4} \quad (5)$$

$$\hat{He} = (c_2 - \hat{En}^2)^{1/2} \quad (6)$$

3. Evaluation Model of Learning Outcomes Achievement

In this paper, learning outcomes achievement is used as the index to evaluate the students' performance and advancement in the teaching-learning process. And it is quantized signifying by the numerical characteristics of the cloud model of learning outcomes, recorded as $\bar{A} = (Ex, En, He)$. The evaluation procedure of learning outcomes achievement is as follows: Firstly, classify the evaluation scale, and describe each grade quantitatively by cloud model. Secondly, construct a comprehensive appraisal system of learning outcomes achievement, and calculate the learning outcomes achievement of each indicator by reverse cloud algorithm according to students' learning data. Finally, compare the cloud similarities between learning outcomes achievement and evaluation grades, then draw a conclusion for subsequent educational reform.

3.1 Evaluation Scale Classification and Quantitative Description

In order to comprehensively evaluate the qualitative and quantitative learning outcomes, we use centesimal system score to describe the evaluation scale and divide it into five grades, that is excellent, good, moderate, inferior and poor, of which the score intervals are correspondingly set as: [90,100], [80,90), [70,80), [60,70), [0,60). Then the numerical characteristics of the cloud model of each evaluation grade can be calculated as follows [16].

$$Ex = (c_{max} + c_{min}) / 2 \quad (7)$$

$$En = (c_{max} - c_{min}) / 6 \quad (8)$$

$$He = k \quad (9)$$

Where k is a constant, and the value can be adjusted according to $En, He \in [0.01, 0.1]$. Here let k is equal to 0.1. c_{max} and c_{min} are the upper and lower limits of score interval. Table 1 shows the classification and description (qualitative and quantitative) of the evaluation scale.

Table 1. Classification and numerical characteristics (Ex_0, En_0, He_0) of evaluation scale

Grade Parameter	Excellent	Good	Moderate	Inferior	Poor
Score Interval	[90,100]	[80,90)	[70,80)	[60,70)	[0,60)

Ex_0	95	85	75	65	30
En_0	1.6667	1.6667	1.6667	1.6667	10
He_0	0.1	0.1	0.1	0.1	0.1

3.2 Learning Outcomes Achievement of Individual Evaluation Indicator

In order to evaluate the students' learning outcomes achievement scientifically, reasonably and effectively, it is necessary to construct a multi-dimensional appraisal system with multiple subjects, multiple methods and multiple criteria to satisfy the internal and external needs of country, society and school. Therefore, quantitative and qualitative indicators are both existed in the system. Assume that the appraisal system has m first-level indicators, recorded as (U_1, U_2, \dots, U_m) , and U_i ($i = 1, 2, \dots, m$) has n_i second-level indicators, recorded as $(U_{i1}, U_{i2}, \dots, U_{in_i})$.

For qualitative indicators, such as classroom performance, ideological and political quality, professional responsibilities, innovative consciousness, teamwork ability and so on, teachers and students both participate in giving scores according to the evaluation criteria, and then the sample set R_x will be formed. However, quantitative indicators can be directly expressed by various test scores throughout the teaching-learning process, which form the sample set R_l . So from Eq. (2) - (6) the learning outcomes achievement of a certain second-level indicator, $\bar{A}_j = (Ex_j, En_j, He_j)$ ($j = 1, 2, \dots, n_i$), can be calculated.

3.3 Learning Outcomes Achievement of Comprehensive Evaluation Indicator

Assume that the weight vector of the first-level indicators is (w_1, w_2, \dots, w_m) , and the weight vector of the second-level indicators under U_i is $(w_{i1}, w_{i2}, \dots, w_{in_i})$, $i = 1, 2, \dots, m$. Where $\sum_{i=1}^m w_i = 1$ and $\sum_{j=1}^{n_i} w_{ij} = 1$. Then according to the algebraic algorithms of cloud model mentioned in [17], the learning outcomes achievement of the first-level indicator U_i can be calculated with consideration of the weight of second-level indicators, and it is written as $\bar{A}_i = (Ex_i, En_i, He_i)$.

$$Ex_i = \sum_{j=1}^{n_i} w_{ij} Ex_j \quad (10)$$

$$En_i = \sqrt{\sum_{j=1}^{n_i} w_{ij} En_j^2} \quad (11)$$

$$He_i = \sqrt{\sum_{j=1}^{n_i} w_{ij} He_j^2} \quad (12)$$

Therefore, the comprehensive learning outcomes achievement can be calculated as follows:

$$\bar{A} = (Ex, En, He) = \left(\sum_{i=1}^m w_i Ex_i, \sqrt{\sum_{i=1}^m w_i En_i^2}, \sqrt{\sum_{i=1}^m w_i He_i^2} \right) \quad (13)$$

3.4 Comparison of Cloud Similarity

In order to evaluate the grade of students' learning outcomes achievement, the cloud similarity is adopted in this paper. It essentially has two perspectives, that is distance and shape [18]. Shape similarity is a value of measuring how similar two clouds are in geometrical shape, which is just related to Entropy En and Hyperentropy He . While distance similarity reflects the variation on lateral position of two clouds that is brought about by expectation changes. In general, when evaluating students' learning outcomes, we expect the average value of scores as higher as possible and the distribution of scores as more concentrated as possible. So it is just necessary to compare the shape similarities between the clouds of learning outcomes achievement $C_j(Ex_j, En_j, He_j)$ and evaluation grade $C_0(Ex_0, En_0, He_0)$. Thus the cloud similarity Sim_s can be calculated as follows:

$$Sim_s(C_j, C_0) = \frac{\min \left(\sqrt{En_j^2 + He_j^2}, \sqrt{En_0^2 + He_0^2} \right)}{\max \left(\sqrt{En_j^2 + He_j^2}, \sqrt{En_0^2 + He_0^2} \right)} \quad (14)$$

The larger the Sim_s is, the more similar the shapes of the clouds are. And in the case of the same expectation Ex , the learning outcomes achievement is positively related to Sim_s .

4. Application and Results

This study takes the course of “Mechanical Operation by Forklift” as an example. The course adopts the blending learning mode that combines the on-line learning with classroom learning. Besides, problem-based learning (PBL) and task-based teaching penetrate the whole teaching process. The teaching is divided into 4 links. Firstly, students learn online course before class at their own speed and complete the pre-class task, then feed back their questions to teachers through the Mooc platform; the teachers can assess the situation of students’ learning from the back end, including the degree of completion, pre-class test scores, the most common mistakes, poorly mastered knowledge and so on, and then elaborate problem sets accordingly. Secondly, in class the teacher guides students to analyze the problems, put forward the hypothesis, test the hypothesis and draw the conclusion, and evaluates the students’ learning status, acquisition of knowledge and innovative consciousness. Thirdly, students train on the simulators and real forklifts successively to perform the classroom task. The training scores, reflecting students’ professional skills and consciousness of safe practices, are recorded by simulators and training teaching management system; the teacher can also evaluate the teamwork ability of the students through their practices. Finally, students complete the online test after class. This part aims at consolidating and examining the key knowledge points. Table 2 shows the evaluation indicator system of classroom learning outcomes and the weight of each indicator.

Table 2. Evaluation indicator system of classroom learning outcomes and indicator weights

First-level Indicator	Second-level Indicator	Assessment Format	Indicator Weight	
Learning Attitude(U_1)	Mooc learning progress(U_{11})	Backstage data of Mooc platform	0.5	0.2
	Learning status in the classroom(U_{12})	Teacher comment	0.5	
Craftsman Spirit(U_2)	Consciousness of safe practices(U_{21})	Backstage data of simulation trainer & teacher comment	0.4	0.2
	Innovative consciousness(U_{22})	Teacher comment	0.3	
	Teamwork ability(U_{23})	Teacher comment & self-evaluation within the group	0.3	
Professional Knowledge(U_3)	Online test score(U_{31})	Backstage data of Mooc platform	0.6	0.3
	Class answering score(U_{32})	Teacher comment	0.4	
Professional Skill(U_4)	Simulated training score(U_{41})	Backstage data of simulation trainer	0.5	0.3
	Practical training score(U_{42})	Data from training teaching management system	0.5	

We choose the 50 students class of Grade 2022 as the sample. According to the learning data collected by Mooc platform, simulators and training teaching management system, the classroom learning outcomes achievement (Ex, En, He) can be calculated from Eq. (2) - (6) and Eq. (10) - (13). Take the lesson “Using forklift to load and unload” as an example, the students’ classroom learning outcomes achievement of each indicator is as shown in Table 3. From Table 3 it can be seen that: First, the comprehensive learning outcomes achievement (U) and that of the first-level indicators (Learning attitude, Craftsman spirit, Professional knowledge and Professional skill) fluctuated at the lower limit of the grade “Good”, and the differences of Sim_s were not great, which mean that the learning effects of first-level indicators were about equal. Second, the

expectations Ex of the indicators U_{12} , U_{21} , U_{31} , U_{42} were all above 80 (at the grade “Good”). En_{31} and He_{31} (expressing the indicator U_{31}) were the smallest among all the indicators, and the cloud similarity was the largest, meaning that the students had a good command of the key knowledge of this lesson and their learning progress was accordant. Although Ex_{12} and Ex_{21} were the highest, the cloud similarities were relatively low. It means that the whole learning status and consciousness of safe practices were good, but there was obvious disparity of the learning progress. Third, the students’ learning outcomes achievement of U_{11} (Mooc learning progress) was at the grade “Moderate”, which directly affected the class answering scores (U_{32}). Therefore, Ex_{32} and Sim_{s32} were the lowest because of the poor preview results. Fourth, as “Using forklift to load and unload” is the first lesson about operating skills, the learning outcomes achievement of U_{41} (Simulated training score) was at the grade “Moderate”, but after simulation training, the results of practical training (U_{42}) had made great progress, Ex_{42} and Sim_{s42} were improved greatly. It means that the learning model of “training on simulators first, then real equipments” is of great benefit to cultivating professional skills. However, the training time needs to be further increased. Finally, the innovative consciousness (U_{22}) and teamwork ability (U_{23}) of the students were evaluated as “Moderate” too. Ex_{23} was higher, whereas Sim_{s23} was lower, that means compared to innovation, the students were better at cooperation, but the whole class had different awareness about teamwork.

Table 3. Classroom learning outcomes achievements and cloud similarities of all levels of indicators for the lesson “Using forklift to load and unload”, U represents the comprehensive outcome

Indicator	(Ex, En, He)	Sim_s	Indicator	(Ex, En, He)	Sim_s
U_{11}	(76.0482,7.6365,1.4901)	0.2146	U_{41}	(75.5301,8.0735,2.0843)	0.2002
U_{12}	(87.8313,6.4940,1.3457)	0.2518	U_{42}	(83.2651,7.9211,1.2237)	0.2083
U_{21}	(87.4096,5.6180,1.4816)	0.2874	U_1	(81.9398,7.0883,1.4197)	0.2310
U_{22}	(75.7711,7.2921,1.2383)	0.2257	U_2	(80.8783,7.3027,2.0277)	0.2203
U_{23}	(77.2771,9.0832,3.0406)	0.1743	U_3	(81.1976,6.3897,2.6195)	0.2324
U_{31}	(85.0723,3.1221,0.1447)	0.5342	U_4	(79.3976,7.9977,1.7090)	0.2042
U_{32}	(75.3855,9.3514,4.1380)	0.1633	U	(80.7422,7.2216,2.0396)	0.2225

With the above analysis, we have taken some measures to improve the teaching. For example, we formed study groups of 5-6 students to reinforce complementary advantages, help and supervise each other and stimulate enthusiasm for learning. Besides, the types of online test were enriched. In addition to objective questions, short answer questions about task analysis were added and the topic backgrounds were expanded to the real professional scenes, which could assess the students’ ability of analyzing and solving problems in a specific simulated situation. What’s more, in order to improve the ability of students’ post competence, we gave more time for them to practice and organized them to participate in realistic jobs in the warehouse. As a result, the classroom learning outcomes achievements of the next lesson “Using forklift to stack” had been significantly improved as Fig. 2 shows.

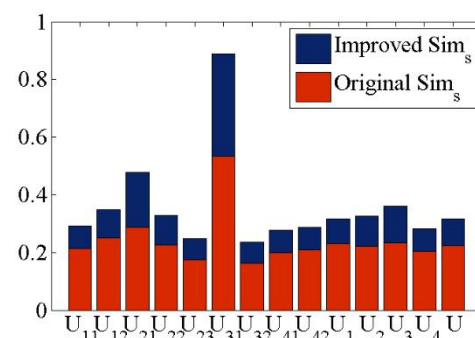
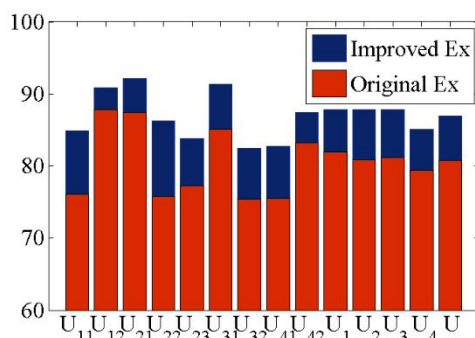


Fig. 2 Superposed bar diagrams to compare the expectations Ex and cloud similarities Sim_s of all indicators (The improved data are for the lesson “Using forklift to stack”, and the original data are for the lesson “Using forklift to load and unload”)

5. Summary

The purpose of evaluating the students' learning outcomes achievement is to demonstrate the performance and progress of their knowledge, skills and abilities after a learning stage by collecting and analyzing the statistical information. By introducing cloud model theory into the teaching-learning process, we manage to provide an evaluation model of curriculum learning outcomes achievement. The results of the application show that our proposed model can realize the transformation of qualitative and quantitative evaluation, and give precise numerical values to represent the students' learning outcomes comprehensively. According to compare the expectation Ex and the cloud similarity Sim_s of each evaluation indicator, teachers can discover the problems in teaching and learning, and then take appropriate measures to improve the quality of teaching. When all the learning data of the whole procedure are involved in, it is available not only for evaluating the class learning outcomes of each stage of curriculum teaching, but also the individual student's. And through analyzing the data of each course by our model, the results will be able to reflect the instructional quality and effect of one specialty, which have actual directive significance to continuous educational reform.

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