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PAPER

Evaluation of Online Learners' Learning Performance Based on Fuzzy Borda Method

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ABSTRACT

Since the traditional evaluation system of learning focuses only on the summative evaluation of learners' test scores, ignoring the process evaluation of learners in learning process, the evaluation system should not only consider the content of the online learning process but also that of face-to-face classroom teaching process to evaluate learners' learning performance in multiple dimensions and levels. This approach evaluates online learning more reasonably, operably and feasibly. To overcome limitation of using more than one method in the evaluation of learning performance, the learning performance of online learners was first evaluated using the principal component analysis method, entropy method, comprehensive indicator method, and TOPSIS method. Based on these four evaluation results, a combination evaluation model of online learners' learning performance was constructed. The Fuzzy Borda method was used to evaluate nine administrative classes of accounting majors in three colleges and universities in Hainan. The results show that simply using a single evaluation method to evaluate the learning performance of online learners has defects, and the evaluation results are too biased. By using the Fuzzy Borda method, multiple evaluation methods can be combined, allowing a single evaluation method to realize complementary advantages and obtain more comprehensive and credible evaluation results. Using the Fuzzy Borda method to systematically evaluate the learning performance of online learners improves the scientificity of evaluation results and provides a new idea and method for the evaluation of online learning performance. The results of this study have significant reference value for using scientific evaluation methods and objective data to evaluate online learning performance, rank online learners scientifically, and summarize teaching experience to improve online learning performance.

KEYWORDS

Fuzzy Borda method, online learners, learning performance, performance evaluation

1 INTRODUCTION

The comprehensive development of educational informatization has made online learning one of the main ways to meet needs of general public to complete

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education. Online learning has the characteristics of a wide range of learning objects and fewer time and space restrictions, playing an important role in the construction of a lifelong learning society for everyone. Especially under the influence of the epidemic, online courses have become an important method of learning. Compared with face-to-face learning in traditional classrooms, online learning breaks through space limitations, offers a wider range of learning content, and provides more personalized learning options in terms of time and place. Learners can customize the learning content and schedule to align with their individual learning ability. At present, major online courses mainly include Massive Open Online Courses (MOOCs) and Small Private Online Courses (SPOCs), whose serves the main functions of learning navigation, learning objectives, resources, discussion and evaluation, so as to meet learners' more personalized learning needs. With massive teaching, online courses pay more attention to the cultivation and development of students' critical thinking and higher-order thinking abilities. Learners can use fragmented time to learn anytime and anywhere, realize the change in "learner-centered" teaching mode, and lead online courses under "Internet + education" to achieve more development and progress. With the acceleration of education informationization, more colleges and universities have adopted online learning methods, and college students have gradually accepted online learning methods, making colleges and universities gradually change from traditional classroom teaching modes to online learning, mobile learning, hybrid learning, and other network learning methods. Diversification of learning styles and networking of learning resources make learning process behavior data and learning outcome data generated by learners increasingly rich, which not only lays a good material foundation for the majority of educators and researchers to carry out in-depth research on teaching and learning but also puts forward an urgent demand for how to use these precious data resources to optimize the learning process and improve the quality of learning.

From the perspective of foreign development, developed countries represented by the United States, Japan, and Germany gradually introduced performance evaluation methods, contents, and concepts into the field of higher education around 1970 and made a more scientific evaluation of higher education performance. In particular, since 1980, with the rise of the performance evaluation movement in the field of higher education in the United States, performance evaluation has begun to enter people's vision and become the focus of the world. Learning performance refers to changes in students' learning performance, engagement, ability, attitude, and performance during the learning process. Moreover, learners' operating interface and interaction, the teacher's attitude towards students, and technical ability play a very important role in learners' participation and learning performance. As the acquisition process of learning performance itself is a complex interaction process of "teachers' teaching and students' learning," and factors affecting teachers' teaching quality and students' learning activities are more complex, scientific evaluation of learning performance is more important. In order to obtain evaluation results of learning performance more scientifically, more evaluation indicators and, especially, more objective criteria should be used to measure them. However, there are also many characteristics of learning performance that cannot be measured by fixed standards and need to be evaluated artificially. Therefore, to improve the quality of learning performance evaluation results, it needs to adopt more scientific standards and more accurate evaluation methods.

2 LITERATURE REVIEW

Chinese colleges and universities have built a large number of online learning platforms, providing massive learning resources and personalized learning methods for the majority of learners and making more learners gradually accept online learning methods. However, the learning performance of learners has also become the focus of education circles. At present, more literature focuses on the construction of an online learning performance evaluation index system. Learning performance evaluation refers to the establishment of an evaluation index system by using scientific evaluation methods and determining the principles of index construction so as to enrich evaluation content and make evaluation results more scientific and accurate. As for the evaluation of learning performance, Martinez-Caro et al. [1] mainly applied the performance evaluation model to the sample of business students to follow the practice of total quality management to improve student satisfaction and continuous improvement. Results showed that the application of this model could improve the effective use of online learning resources and achieve an appropriate quality level. Results of Maqableh et al. [2] showed that during the COVID-19 epidemic, students turned to online learning, and there were problems such as technology, mental health, time management, and balancing life and education. Various solutions and suggestions were proposed to improve the online learning experience and improve students' satisfaction. Gündüz et al. [3] developed and evaluated the effectiveness of problem-based online learning environments, and research results showed that problem-based online learning environments had a positive impact on learning. Zhang et al. [4] developed an efficient online learning algorithm to evaluate the learning performance of online learners by using the correlation of learning models among local learners. Jo et al. [5] used a structural equation model to test the fitting of the hypothesis model on 188 college students from a university in South Korea. Results showed that learners' time-related online behavior played a mediating role in mental function and learning performance. Sims et al. [6] argued that scientific evaluation of learning performance is of high priority and is influenced by a wide range of evaluation strategies. In the context of the online teaching environment, the understanding of teachers, learners, and developers regarding online learning equipment plays a crucial role in determining the utilization of online learning resources and its impact on learning performance. Martin [7] believed that learning management systems and desktop applications had a certain degree of impact on learners' online learning performance. Griff et al. [8] evaluated the effectiveness of an adaptive online learning system on students' learning performance in undergraduate anatomy and physiology courses, and results showed that the use of an online learning system could have an impact on the improvement of learning performance measurement, grade distribution, and retention rate. Nikou et al. [9] believed that micro-learning through mobile terminals could best improve the scientific motivation and academic performance of high school students. 108 students from a European high school were randomly assigned to a control group and an experimental group, and experimental results found that micro-learning using mobile terminals could enhance students' basic psychological needs for self-perceived autonomy, competence, and relevance and improve students' test scores in factual knowledge. Chen et al. [10] showed that video-based multimedia materials could bring the best learning results and the most positive emotions to language learners. Dynamic multimedia materials containing video and animation were more suitable for visualizers than static multimedia materials

containing text and images, improving learners' learning performance [11]. Sung et al. [12] conducted a meta-analysis and research synthesis on the impact of integrated mobile devices on teaching and learning, in which 110 experimental and quasi-experimental journal articles published between 1993 and 2013 were coded and analyzed. Results showed that mobile learning could promote learners' learning motivation and learning performance. Lile et al. [13] believed that attention to learning performance evaluation was strengthened by requirements expressed by society today, discussed the importance of cultivating information literacy within students in higher education, and put forward a comprehensive assessment tool that could make a more scientific evaluation of learning outcomes and learning processes. In a survey of 83 teachers, Hargreaves [14] suggested that learning assessment should be transformed into a learning process and diversified learning methods should be adopted to enrich students' learning processes and improve their learning performance. Adair-Hauck et al. [15] introduced a prototype of the Integrated Performance Assessment (IPA), illustrated a sample IPA, and discussed how IPA-based classroom research had demonstrated the counterproductive effect of integrated performance assessment on teachers' perceptions of their teaching practices. Wang et al. [16] discussed the relationship between students' traits and course learning performance in an online learning environment. 256 students participated in this study, and results showed that students with online learning experience tended to have more effective learning strategies when learning online courses, so they had a higher level of motivation in online courses. It was suggested that students' self-regulated learning behaviors should be promoted in online learning environments to facilitate teaching and learning experiences. Farrell et al. [17] outlined the application of techniques to support and enhance diagnostic, formative, and summative assessments. Kearns [18] believed that assessment of student learning was a basic aspect of teaching. Results showed that assessment of student learning performance in the online environment needed to consider problems of learning workload and learning time management.

It can be seen from the existing research literature that there are many factors affecting learning performance, including people themselves, the environment, the project or work itself, management mechanisms, etc. Learning performance is not only a result of learning but also of ability and quality, including learners' ability to master learning, use information and tools, communicate, collaborate with information literacy, and so on. Learning performance manifests itself in various forms, not only in learning efficiency and learning results. Much research literature focuses on learning strategies chosen by learners, such as their ability to discover and solve problems, their ability to communicate and cooperate, improvement of advanced thinking ability, and mastery of various skills, as components of learning performance. Online learning performance based on a network teaching platform should include the learning process and learning results, including all aspects of learners' ability, accomplishment, sustainability, attitude, etc. In the teaching based on the network teaching platform of colleges and universities, the development of a scientific and practical learning performance evaluation system is conducive to improving the teaching quality of colleges and universities and is conducive to improving college students' learning ability and information literacy. Therefore, this study uses the Fuzzy Borda method to comprehensively evaluate the learning performance of online learners, which provides a new space for the study of online learning evaluation models. In order to better evaluate online learning, it promotes the teaching quality of colleges and universities and suggests improvement in students' learning performance. To make up for shortcomings in online learning evaluation, it promotes the cultivation of students' learning abilities, the construction of online teaching platforms, and a reference for teachers and researchers who need to evaluate the performance of online learning.

3 RESEARCH METHODS

3.1 Model introduction

At present, there are many methods for multi-index comprehensive evaluation. Common methods include the analytic hierarchy process (AHP), fuzzy comprehensive evaluation, TOPSIS method, etc. These methods can only reflect the learning performance of online learners from a certain aspect and have certain limitations when conducting a comprehensive evaluation of their learning performance. However, at the same time, these methods still have defects and problems. Due to different purposes of evaluation, these methods often only consider the importance of one aspect of the indicator while ignoring the importance ranking of other aspects, so the weight of the indicator is sometimes inconsistent with the actual situation. The Fuzzy Borda rule overcomes the above mentioned shortcomings and can make assessment results close to actual situation. Therefore, this method is chosen in this study when evaluating learning performance of online learners. Before evaluation of Fuzzy Borda, other comprehensive evaluation methods, such as principal component analysis (PCA), fuzzy comprehensive evaluation, TOPSIS, etc., should be adopted to obtain evaluation results. After completion of the evaluation, the Fuzzy Borda method should be used to evaluate the combinatorial evaluation model to get the final score of online learners' learning performance evaluation. The specific calculation steps of the Fuzzy Borda method are described below.

To begin with, membership degree should be calculated, as shown in formula (1).

$$\mu_{ik} = \frac{x_{ik} - \min\{x_k\}}{\max\{x_k\} - \min\{x_k\}} * 0.9 + 0.1 \tag{1}$$

In the formula (1), $i = 1,2,...,n$, k represents the various possible comprehensive evaluation results. Here, $k = 1$ represent entropy value method, $k = 2$ represents comprehensive index method, and $k = 3$ represents TOPSIS method. x_{ik} represent score of the ith evaluation object under the kth method. $\{x_k\}$ represent score collections of n objects under the kth method. μ_{ik} represent the "optimal" belongs to membership of x_i under the kth method. The fuzzy frequency is calculated as shown in formula (2).

$$f_{ih} = \sum \mu_{ik} \delta_{kh} \tag{2}$$

W_{ih} is calculated based on fuzzy frequency, as shown in formula (3).

$$W_{ih} = \frac{f_{it}}{\sum_t f_{it}}, t = 1,2,\kappa\ ,n \tag{3}$$

The ranking scores of online learners are then transformed, as shown in formula (4).

$$Q_{it} = 60 + (n - t)/(n - 1) * 40 \tag{4}$$

Here Q_{it} represents score for which x_i ranks t in the order relation. Finally, Fuzzy Borda score F is calculated, which is final evaluation result of online learners' learning performance level, and is shown in formula (5).

$$F = \sum_h W_{it} Q \tag{5}$$

3.2 Data sources

In this study, 398 accounting major students from three universities in Hainan Province, including nine administrative classes, were selected for evaluation. The original evaluation data was collected from eight professional courses during the spring semester of 2021–2022 academic year. The average score of for each administrative class was calculated by considering the scores obtained in these eight professional courses. Table 1 presents the descriptive results of raw achievement data for all the students.

Table 1. Descriptive results of original performance data

School Name	Class Name	Minimum Value	Maximum Value	Average Value	Standard Deviation	Median
School 1	Accounting Class 1, Grade 2019	64	81	74.25	5.392	74.5
	Accounting Class 2, Grade 2019	62	89	75.25	8.464	74
	Accounting Class 3, Grade 2019	64	82	74.25	5.445	74
School 2	Accounting Class 1, Grade 2019	50	93	74.375	13.887	75
	Accounting Class 2, Grade 2019	63	88	71.375	8.035	69.5
School 3	Accounting Class 1, Grade 2019	61	94	76.75	9.823	75
	Accounting Class 2, Grade 2019	65	82	70.5	5.451	70
	Accounting Class 3, Grade 2019	62	82	70.625	6.545	70
	Accounting Class 4, Grade 2019	55	87	74	10.542	75.5

As observed from Table 1, the results of eight courses across yhe nine accounting classes in the three universities show similarity.

4 RESULTS ANALYSIS

4.1 Results of TOPSIS

Table 2. Results of TOPSIS

School Name	Class Name	Positive Ideal Solution Distance *D*	Negative Ideal Solution Distance *D*-	Relative Proximity *C*	Sorting Result
School 1	Accounting Class 1, Grade 2019	38.471	37.59	0.494	4
	Accounting Class 2, Grade 2019	29.462	42.509	0.591	2
	Accounting Class 3, Grade 2019	36.442	35.313	0.492	5
School 2	Accounting Class 1, Grade 2019	40.262	43.128	0.517	3
	Accounting Class 2, Grade 2019	41.388	31.875	0.435	7
School 3	Accounting Class 1, Grade 2019	26.306	45.596	0.634	1
	Accounting Class 2, Grade 2019	41.376	28.267	0.406	8
	Accounting Class 3, Grade 2019	42.131	28.213	0.401	9
	Accounting Class 4, Grade 2019	37.47	34.943	0.483	6

As can be seen from Table 2, $D+$ and $D-$ represent the distance between the evaluation object and positive and negative ideal solutions, respectively. C represents the degree of proximity between the evaluation object and the optimal scheme. The larger the value, the closer it is to optimal scheme. Based on the rankings, Class 1, Grade 2019 of School 3 holds the first place, Class 2, Grade 2019 of School 1 in the second place, and Class 1, Grade 2019 of School 2 in the third place, indicating that the results of students majoring in accounting in these three schools are relatively balanced.

4.2 Results of composite indicator

Table 3. Results of comprehensive indicator

School Name	Class Name	Composite Indicator	Sorting Result
School 1	Accounting Class 1, Grade 2019	1.080	4
	Accounting Class 2, Grade 2019	1.173	2
	Accounting Class 3, Grade 2019	1.081	3
School 2	Accounting Class 1, Grade 2019	0.978	6
	Accounting Class 2, Grade 2019	0.770	7
School 3	Accounting Class 1, Grade 2019	1.355	1
	Accounting Class 2, Grade 2019	0.713	9
	Accounting Class 3, Grade 2019	0.716	8
	Accounting Class 4, Grade 2019	0.993	5

From Table 3, it is evident that the comprehensive indicator method transforms each indicator through calculations and finally obtains a comprehensive indicator, which is used for monitoring and comparison at a comprehensive level.

4.3 Principal component results

Table 4. Principal component results

School Name	Class Name	Principal Component Score	Sorting Result
School 1	Accounting Class 1, Grade 2019	–0.362	6
	Accounting Class 2, Grade 2019	0.021	4
	Accounting Class 3, Grade 2019	–0.037	5
School 2	Accounting Class 1, Grade 2019	1.473	1
	Accounting Class 2, Grade 2019	–0.364	7
School 3	Accounting Class 1, Grade 2019	0.888	2
	Accounting Class 2, Grade 2019	–0.553	8
	Accounting Class 3, Grade 2019	–1.545	9
	Accounting Class 4, Grade 2019	0.478	3

As can be seen from Table 4, principal component method is adopted to calculate the top 3 of Accounting Class 1, Grade 2019 of School 2, Accounting Class 1, and Class 4, Grade 2019 of School 3.

4.4 Entropy method results

Table 5. Entropy method results

School Name	Class Name	Information Entropy Value *e*	Information Utility Value *d*	Weight Coefficient *w*	Sorting Result
School 1	Accounting Class 1, Grade 2019	0.9989	0.0011	0.0435	9
	Accounting Class 2, Grade 2019	0.9973	0.0027	0.1024	4
	Accounting Class 3, Grade 2019	0.9989	0.0011	0.0442	8
School 2	Accounting Class 1, Grade 2019	0.9924	0.0076	0.2923	1
	Accounting Class 2, Grade 2019	0.9974	0.0026	0.0991	5
School 3	Accounting Class 1, Grade 2019	0.9966	0.0034	0.1323	3
	Accounting Class 2, Grade 2019	0.9988	0.0012	0.0473	7
	Accounting Class 3, Grade 2019	0.9982	0.0018	0.0690	6
	Accounting Class 4, Grade 2019	0.9956	0.0044	0.1700	2

As can be seen from Table 5, entropy is a physical unit of measurement. The higher the entropy, the more chaotic the data, the less information it carries, the smaller the utility value, and thus the smaller the weight. Entropy rule is a research method to determine the weight based on information value provided by entropy.

4.5 Fuzzy Borda sorting results

Table 6. Fuzzy Borda sorting results

School Name	Class Name	Fuzzy Borda Sorting Results
School 1	Accounting Class 1, Grade 2019	2
	Accounting Class 2, Grade 2019	3
	Accounting Class 3, Grade 2019	5
School 2	Accounting Class 1, Grade 2019	7
	Accounting Class 2, Grade 2019	9
School 3	Accounting Class 1, Grade 2019	8
	Accounting Class 2, Grade 2019	1
	Accounting Class 3, Grade 2019	6
	Accounting Class 4, Grade 2019	4

As it can be seen from Table 6, through the evaluation of Hainan Province, accounting major students at the three universities have a total of nine administrative classes. It can be seen that the overall learning performance of Accounting Class 2, Grade 2019, of School 3 is the best, ranking first. The possible reason is that teachers adopt more

flexible and diversified teaching methods in online teaching. It stimulates the enthusiasm of students to participate in the course learning, helps students understand the objectives of learning tasks, clears activity requirements and matters needing attention, and helps students' master a specific arrangement of learning activities. Teachers can inform students of course content, learning theme, resources, start and end times, and other information; help students establish a scaffold for completing learning activities, promote teacher-student interaction, help students feel the help and support in an online learning environment; arouse students' attention to the course; and increase achievement of the course objectives. In addition, it reminds students to prepare to participate in the learning and discussion activities of this course, establishes connections between teachers and students, and stimulates students' learning interest and participation enthusiasm. Prompt information helps learners understand the course objectives and activity requirements in advance. At the same time, Accounting Class 1, Grade 2019, and Accounting Class 2, Grade 2019, of School 1, rank in second and third place, indicating that the overall online learning performance of the accounting major in School 1 is relatively good and at a high level. The possible reason is that for e-learning, under the premise of system or platform support, the design of learning activities must ensure the maximum amount of information transmission, be truly student-centered, and have sufficient understanding of learner motivation, style, and evaluation. Teachers must set up multi-link evaluation criteria for online teaching. A multi-pronged approach to evaluation and the distribution of evaluation links can promote improvement in learners' learning quality and guarantee the effectiveness of teachers' professional development. Learning scoring mechanisms should be designed and applied to each network behavior in more detail, such as the number of videos viewed, fast forward pauses, time intervals between downloading and expanding resources, and time spent on the topic post. This is a manifestation of concrete process evaluation and can make evaluation mechanisms more perfect and fair.

5 DISCUSSION

As one of the most extensive forms of higher education, there are many studies on online learning at home and abroad, which mainly focus on the study of the rules of online teaching and learning, the design of teaching materials and learning resources, the construction and evaluation of online courses, the online learning environment, and the online learning platform. However, the use of performance evaluation is not particularly rich in research literature based on the online teaching platforms of colleges and universities. Online learning creates a variety of opportunities for teachers and students to learn and communicate, but problems emerge in an endless stream, which will directly affect the implementation effect of online courses and reduce the quality of online learning. In the process of studying learning performance, scholars will inevitably mention learning performance, learning satisfaction, course participation, learning interest, and other aspects. Based on a literature review and theoretical support, this study sorts out evaluation dimensions of online learning performance and analyzes the impact of different activity types on online learners through a more scientific and comprehensive evaluation of online learners' learning performance, so as to summarize characteristics of effective online activities and propose effective online learning activity design strategies. After the evaluation method and evaluation indicator system are determined, it is necessary to combine the calculation model of the evaluation method with the evaluation indicator. To some extent, the process of combining the online learning performance portfolio evaluation model with the evaluation indicator proposed in this study is a process from theory to practice.

It is necessary to introduce the evaluation indicator system into the evaluation model for interpretation and explanation, and finally realize the organic combination of the evaluation indicator system and the combination evaluation model. In this study, a combination evaluation model based on the Fuzzy Borda method solves the difference problem between the results of different evaluation methods and can combine the advantages of each single evaluation method to make evaluation results more accurate, indicating that combination evaluation methods can be used in the evaluation of online learning performance. As evaluation of online learners' learning performance is relatively complex, there is little difference in the evaluation of each learner in a certain region. In combination evaluation with the Fuzzy Borda method, evaluation results and order scores of a single evaluation model are "amplified," so that evaluation results of a single evaluation method that are not obvious are combined. Variation is more dramatic, and results are more intuitive.

6 CONCLUSIONS

Informationization in education is highly popular, and online learning is developing rapidly in the field of education. Online learning requires learners to learn more autonomously and collaboratively. In the field of educational technology research, online learning performance evaluation has become one of the research hot spots. Knowledge and skills, emotion and attitude, values, and learning processes and methods in online learning are contents that learners need to adopt in their evaluation of learning performance. Online learning performance evaluation should not only pay attention to learners' final exam results, but also pay attention to the evaluation of learners' daily learning processes, and conduct multidimensional and multi-level evaluations of learners. To obtain a more scientific and accurate level of online learning performance, this study takes nine administrative classes of accounting majors in three colleges and universities in Hainan Province, China, as objects and uses four methods, including PCA, entropy, comprehensive index, and TOPSIS, to evaluate the learning performance of online learners. On the basis of these four evaluation results, the Fuzzy Borda method is used to evaluate combinations. The research mainly draws the following three conclusions: (1) Simply using a single evaluation method to evaluate the learning performance of online learners has defects, and evaluation results are too one-sided. (2) The Fuzzy Borda method can combine more evaluation methods so that a single evaluation method can realize complementary advantages, and obtain more comprehensive and credible evaluation results. (3) The Fuzzy Borda method is adopted to systematically evaluate the learning performance of online learners, which improves the scientificity of evaluation results. It is suggested that further research be carried out in such aspects as further improving the evaluation indicator system of online learning performance by interviewing and issuing questionnaires, increasing the number of survey objects, and applying the Fuzzy Borda method to the online learning performance results of courses in different disciplines in the future.

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