How Instructors Evaluate an e-Learning System? An Evaluation Model Combining Fuzzy AHP with Association Rule Mining

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Abstract

Online learning is becoming increasingly popular as a result more courseware is being converted into digital materials, resulting in the rapid development of e-Learning systems. The ways in which users (particular instructors) evaluate e-Learning systems are an important issue. In this study, the Fuzzy Analytic Hierarchy Process (FAHP) and Association Rule Mining methods are combined to rank criteria for evaluating e-Learning systems in order of importance. The proposed evaluation model comprises three steps. In step 1, a hierarchal structure of evaluation criteria is established. In step 2, 30 instructors who have practical experience of e-Learning system are interviewed according to this hierarchal structure. Finally, in step 3, a fuzzy mechanism is utilized to normalize the semantic variation among domain experts. Then, the normalized results of the questionnaires are analyzed to obtain the fuzzy weights (via FAHP) and association rules (via Association Rule Mining) among the evaluation criteria. The results of the analysis reveal that "connection quality", "ease of use", "visualization", "waiting time" and "graphical arrangement of interface" are the top five criteria for evaluating an e-Learning system. A developer of an e-Learning system can improve user experience using these criteria and their priorities accordingly.

Keywords: e-Learning, e-Learning system evaluation, Fuzzy AHP, Association rule mining

1 Introduction

Recently, the Internet has been widely used by people in the world. According to the "Digital in 2017 Global Overview" report published by We Are Social and Hootsuite, the total number of network users in the world has reached 3.7 billion, which is more than half of the world's population, and it is estimated the growth of the number of network users will continue at a rate of 0.3 billion each year. From this report, it can be found network has already become an indispensable part of human life. Further, the continuously increased network bandwidth allows users to access and exchange a wide range of knowledge and information via network, and this also contributed the introduction of e-Learning into the educational field [1-2]. Because of promotion and resources from the domestic and the international environment, the development of e-Learning system has matured, more and more instructors and learners do online teaching or learning through these systems, such as Moodle, eCampus and Wisdom Master [3].

Recent year, the appearance of Massive open online courses (MOOCs), has attracted lots of participants and is becoming popular for e-Learning [4]. This newly online learning mode lead more courseware is converted into digital materials, resulting in the rapid development of various O2O (online to offline) e-Learning platforms, such as Coursera and edX [2]. MOOCs provide users with new experiences and opportunities in teaching and learning in different ways [5]. To date, online teaching and learning through e-Learning systems is considered to be a trend of modern education [6], many higher education institutions in the world are looking at the e-Learning system as an effective way to assist them in managing the curriculums and instructional materials [7]. More and more universities are planning to offer online education programs through the platform of e-Learning [8-9]. And, there are also increasing universities and colleges that have changed their certain traditional classroom courses to be courses for teaching and learning through e-Learning platforms.

Generally, an e-Learning system environment supports the well-structured, synchronized, and multimedia presentation of instructional material [10]. Such systems must provide users with easy, intuitive, and fast access to content [11]. However, instructors and learners frequently refuse to use of e-Learning systems for teaching or learning, owing to their complex menus and operating environment. Users require proper guidance when they try to familiarize themselves with the operating environment of a new system [12-14]. The builders of such systems must

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understand the functionality and interface that users need as the basis of system development. Therefore, analyzing the requirements of users and establishing a complete evaluation mechanism are critical for expanding the popularity of e-Learning systems. However, evaluating the advantages and disadvantages of e-Learning systems from user's perspective is a crucial challenge.

There are two categories of e-Learning users, namely, learners and instructors. Most researches focused on learner behavior, such as e-Learning system adoption [15-17], the satisfaction of learners with e-Learning systems [18-19], and the learner's attitude, intention and behavior toward e-Learning system [12, 20-25]. Summarize their research findings, the ease of use, the perceived usefulness, self-control, etc. are very important factors toward users' usage intention and usage satisfaction. However, these researches have not discussed how to enhance these important factors of e-Learning system. Besides, few of them discussed the evaluation factors from the perspective of instructors who represent another important group of e-Learning users [26]. For e-Learning operation, the activities of instructors, including material generation and assessment design, are quite different from those of general users, such as material navigation. If an e-Learning system wants to provide users with good interaction and communication interfaces to meet user-required teaching and learning quality, the e-Learning system must first have a good functional framework to enable, for example, test scoring and interactive teaching, as well as a friendly operating environment for use by instructors, so that the instructors can successfully design and teach e-Learning courses. Therefore, to understand the evaluation factors for e-Learning system from instructor perspective is an important issue.

In view of the above facts, this study proposes an integrated systematic evaluation model construct a framework for evaluating key factors that concerns of instructors for e-Learning systems. In this study, the proposed evaluation model consists of three stages that combines two analysis methodologies of fuzzy analytic hierarchy process (FAHP) and Association Rule Mining are detailed in Section 3. To validate the feasibility of the proposed evaluation model, a case study is implemented and the analysis results are shown in Section 4. By providing the comparison results of instructor against leaner, a developer of an e-Learning system can improve user experience using these criteria and their priorities accordingly.

2 Review of Literature

2.1 e-Learning System

The definition of e-Learning is the use of computer network technology, primarily through the Internet or some intranet to transfer all kinds of knowledge and instruction to network users [27]. Through e-Learning, a user can do online teaching and learning at any place and at any time. In other words, since its emergence, the e-Learning has gradually replaced the traditional classroom teaching and learning modes, enabling instructors and learners to get rid of the bond of having to teach and learn at fixed places and fixed class hours. That is, an e-Learning user in an environment having available network, computer and multimedia device can flexibly do distance teaching and online learning activities [28].

Up to date, many e-Learning systems have been developed, such as Moodle, eCampus and Wisdom Master, and these systems have been widely used by different educational fields [29-32]. Actually, these e-Learning systems are generally similar to one another in terms of their basic functions and frameworks [33]. According to research of Ismail, an e-Learning system framework should basically include the functions of Delivery of Learning Programs, Collaboration between Learners, and Evaluation [34].

2.2 Evaluation of e-Learning System

Presently, the e-Learning systems used in different educational fields are not all the same, and instructors or learners usually have to comply with the e-Learning systems provided by the educational institutions when they teach or learn. This situation will frequently force instructors and learners to encounter with and adapt themselves to different e-Learning systems [2-4]. With respect to system functions, while different e-Learning systems are not exactly same in their system functions, their core functions usually include Online Courses, Online Tests, Learning Material Management, Evaluation of Learning, and Course Discussion [35-37]. However, e-Learning systems might vary from one another in terms of their operation interfaces and system environmental quality. In view of this fact, the establishment of a complete systematic evaluation model for evaluating e-Learning systems can provide e-Learning system developers or users with a basic reference when they are trying to set up and choose a good e-Learning system. Hwang et al. had mentioned that a good e-Learning system evaluation mechanism not only helps users find the e-Learning environment most suitable for them, but also upgrades the quality of teaching and learning [38].

As can be found from literature related to e-Learning systems, many past studies used an empirical research method and directly viewed from the point of "user behavior" to explore how the factors of usefulness, satisfaction, computer self-efficacy and so on influence user intention to adopt e-Learning systems in teaching and learning [39-41]. While there were also many studies that included other factors, such as information quality and system quality, in the exploration of the behavior of using e-Learning systems [24, 42-43].

However, these studies neglected the exploration from the angle of "system development" to find out what technological factors and functional factors users are really concerned about when they use the e-Learning systems.

In view of the above fact, in this study, we try to combine the FAHP method in the science of decision-making with the Association Rule Mining in the data mining to find out what systematic factors and functional factors are deemed important by users when they consider the use of e-Learning systems, so as to compensate the insufficiency in the present research field of e-Learning.

2.3 Fuzzy Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) is a Multiple Criteria Decision Making (MCDM) method that was proposed by Saaty in 1977, which has been extensively applied in ranking, evaluation and prediction [44-45]. The method structuralizes the complex decision making issues and provides decision maker with the important weights and priority of the evaluation factors in the decision problem. As Saaty mentioned, the application of AHP requires that a system can be divided into several layers and factors, and a hierarchical structure formed among all factors. In this structure, each of layer is independence [46].

However, AHP is commonly criticized for its inability to accommodate the imprecision and uncertainty associated with mapping decision-makers' perceptions [47-48]. Therefore, Van Laarhoven and Pedrcyz developed the Fuzzy Analytic Hierarchy Process (FAHP) that integrates Fuzzy theory with AHP [49]. FAHP can mitigate the disadvantage of fuzziness and subjective opinions that arise from a pairwise comparison of factors in the AHP expert questionnaire survey. In which way the deviation of the analysis results given by AHP might be reduced [50].

Since FAHP can take many evaluation dimensions and rules into consideration at the same time, it is doubtless an appropriate analytical method for evaluating a highly diversified and complicated information system like the e-Learning system [51-52]. However, FAHP involves more complex calculation steps than the traditional AHP, which are detailed below.

(1) Construct the hierarchical evaluation structure. Verify the decision-making problem to be evaluated, and select the dimensions, criteria and alternatives for the target decision-making problem to construct the hierarchical evaluation structure.

(2) Compare components pairwise. After the hierarchical evaluation structure has been constructed, adopt the nine-level pairwise comparison scale that was proposed by Saaty between the factors, as shown in Table 1 [53]. Then, convert the nine levels into triangular fuzzy semantic membership functions [54-56].

Table 1. Pairwise comparison scale and converting triangular fuzzy numbers

Scale	Definition	$(\tilde{M}_{ij})\,(L_{ij}, M_{ij}, R_{ij})$
1	Equal importance	$\tilde{1}$ (1, 1, 3)
3	Moderate importance	$\tilde{3}$ (1, 3, 5)
5	Strong importance	$\tilde{5}$ (3, 5, 7)
7	Demonstrated importance	$\tilde{7}$ (5, 7, 9)
9	Extreme importance	$\tilde{9}$ (7, 9, 9)

(3) Build pairwise comparison matrix. On the upper triangular part of the pairwise comparison matrix *A*, place the evaluation value of the comparison result for a group of factors made up of *A1, A2, A3,…,* An obtained by an expert. Place the reciprocal of the value at the corresponding position in the lower triangle, $a_{ij} = 1/a_{ji}$, where aij represents the priority of factor *i* relative to that of factor *j*. The pairwise comparison matrix A shown in equation (1):

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & \cdots & a_{ij} \\ 1/a_{12} & 1 & \cdot & \cdot & a_{2j} \\ \cdot & \cdot & 1 & \cdot & \cdot \\ \cdot & \cdot & \cdot & 1 & \cdot \\ 1/a_{1j} & 1/a_{2j} & \cdot & \cdot & 1 \end{bmatrix} \quad (1)$$

(4) Build the fuzzy positive reciprocal matrix. Through the above matrix *A*, we convert the matrix value of the factors into the triangular fuzzy numbers $\tilde{M}_{ij}$ by using Table 1. And we build the fuzzy positive reciprocal matrix *M*, where , $\tilde{M}_{ij}$ is the relative fuzzy number of factor *i* to factor *j*, and $\tilde{M}_{ji} = 1/\tilde{M}_{ij}$.

(5) Translate the matrix value of the factors into the triangular fuzzy numbers ($\tilde{M}_{ij}$) [57]. Based on Table 1, where $\tilde{M}_{ij}$ ((L_{ij}, M_{ij}, R_{ij}) is the fuzzy number of factors between factor i and factor *j*.

(6) Calculate fuzzy weights. Obtain the overall triangular fuzzy numbers M' (L'_i , M'_i , R'_i) of all factors and by using the calculation of geometric mean. The triangular fuzzy numbers shown in equation (2) to (4):

$$L'_i = GEOMEAN\,(L_{11},\ L_{12},\ L_{13},\ \ldots L_{ij}) \quad (2)$$

$$M'_i = GEOMEAN\,(M_{11},\ M_{12},\ M_{13},\ \ldots M_{ij}) \quad (3)$$

$$R'_i = GEOMEAN\,(R_{11},\ R_{12},\ R_{13},\ \ldots R_{ij}) \quad (4)$$

Then, sum up the triangular fuzzy numbers of n factors, to obtain the sums L''_i , M''_i and R''_i of the fuzzy numbers. Finally, calculate the triangular fuzzy weights (W_i) based on the ratio between two numbers. The calculation of triangular fuzzy weights shown in equation (5):

$$W_i = (WL_i\,,\, WM_i\,,\, WR_i) = \left(L_i' / L_i''\,,\, M_i' / M_i''\,,\, R_i' / R_i'' \right) \quad \textbf{(5)}$$

(7) Find the best Non-ddfuzzy Performance (BNP) value and perform normalization. Defuzzify the triangular fuzzy weights obtained in the previous step, convert them into a real number DW_i, and set the sum DW_i of all factors to one. Perform normalization and obtain the final weight DW_i of each factor. The calculation of BNP and normalization shown in equation (6) and (7):

$$DW_i = \frac{\{(WR_i - WL_i) + (WM_i - WL_i)\}}{3} + WL_i \quad \textbf{(6)}$$

$$DW_i' = \frac{DW_i}{\sum_{i=1}^{n} DW_i} \quad \textbf{(7)}$$

(8) Determine priority of each criterion. The above steps yield the fuzzy relative weight NW_i with *i* dimensions and the relative weight NWij of criteria *j* under dimension *i*. To obtain the fuzzy absolute weight NW_k of sub-factor *k*, it requires the series of hierarchy, shown as NW_k. The calculation of fuzzy absolute weight shown in equation (8):

$$NW_k = NW_i \times NW_{ij} \times NW_{ijk} \quad \textbf{(8)}$$

2.4 Association Rule Mining

Association Rule Mining is a data mining method that was proposed by Agrawal et al. in the 1990s [58]. The method defines set *I = {i_1,i_2,i_3…i_m }* as a set of specific items, and the D as the set of all transactional events *T*, where each datum *T* is a subset of any item in *I*, such that $T \subseteq I$, where T is a nonempty subset of *I*, and is assigned a unique transaction ID (*TID*). The number of items in the Itemset is the length of this Itemset. Assume *K* is the length of the Itemset, which is then called the k-Itemset. Assume Itemset $X \subseteq I$, and if $X \subseteq T$, then T will contain *X*, which is also contained in *D* with a support value *Supp(X)*, which is the probability that *D* contains Itemset *X*.

The form of Association Rule Mining is defined as *X→Y*, where $X \subseteq I$, $Y \subseteq I$ and $X \cap Y$. Each criterion includes two parameters, namely, "Support" and "Confidence", which judge whether this criterion has existence meaning. Assume that probability that *T* in *D* contains *X* and *Y*, *Supp(X→Y)* (*Supp(X*$\cup$*Y)*), is *s%*; moreover, assume that the probability that *T* in *D* contains *Y* when it contains *X*, *Conf(X→Y)* (*Supp(X*$\cup$ *Y)/Supp(X)*), is *c%*. For a valid rule, the parameters Support (*Supp(X→Y)*) and Confidence (*Conf(X→Y)*) must be equal to or larger than the minimum support (*minsupp*) and minimum confidence (*minconf*), respectively. Only the rule that satisfies this condition is both meaningful and representative for researcher.

While the FAHP can find out what evaluation rules are important to users, the Association Rule Mining is helpful in finding which important evaluation rules have causality (a cause-and-effect relationship) between them [50].

3 Research Methodology

To elucidate a user's factors for evaluating an e-Learning system, a scoring method is utilized to rank those factors. The proposed methodology applies FAHP to analyze the responses to questionnaires from domain experts and generate the priorities of the evaluation factors from their opinions. A developer of an e-Learning system can use the results of such an analysis of priorities to improve the user experience. Figure 1 presents the three steps of the proposed analysis model.

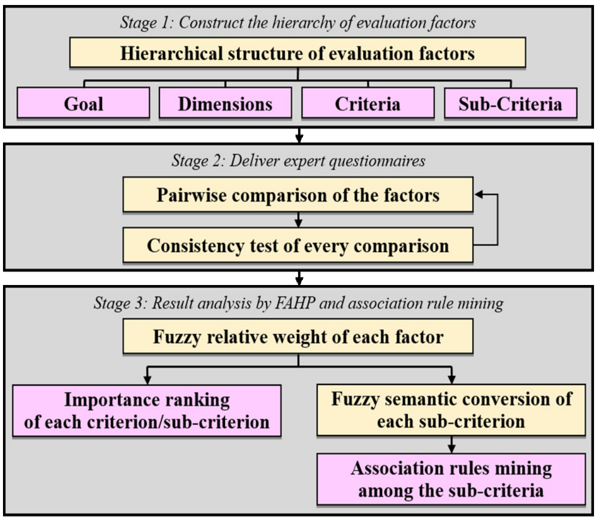

Figure 1. The analysis model for e-Learning system

Satge 1. Construct the hierarchy of evaluation factors. To help to score the e-Learning system, some appropriate evaluation dimensions, factors and sub-factors are extracted through the relational market researches and literatures. Furthermore, an expert panel is organized to conduct multiple for expert questionnaire design. As is typical, some evaluation factors are related to each other. For example, the system stability (C2) of the e-Learning system strongly interacts with the transmission quality (C1). Therefore, based on the interview results, multiple dimensions, criteria and sub-criteria are included in hierarchy of evaluation factors and classified, and the expert questionnaire is developed based on this hierarchy.

Satge 2. Deliver expert questionnaires. To understand how users evaluate an e-Learning system and the scoring factors they use in so doing, 30 professors in Taiwan were interviewed over two months. Their opinions were elicited using an expert questionnaire (which was designed in Step 1). All participants had taught courses related to information technology (or information management). Participants were asked if they have the teaching experience via using e-Learning system. The participants were asked to compare pairs of evaluation factors. To ensure the validity of the questionnaire, every comparison was checked against each other for consistency using consistency test [59].

Satge 3. Result analysis by FAHP and Association Rule Mining. Two analysis streams in Step 3 are FAHP and Association Rule Mining. In the first analysis stream, the collected expert questionnaires are analyzed using FAHP. A nine-point scale (where nine is the highest score) is adopted in the design of the AHP questionnaires. However, the results of the interviews revealed that the experts all used widely varying standards. For example, some participants gave a highest score of five, whereas others gave a lowest score of five. Therefore, a fuzzy mechanism is used to normalize the scores of the domain experts. These normalized scores are further analyzed via FAHP to obtain the fuzzy relative weight of each evaluation factor. Further, calculating the fuzzy absolute weight of each criterion and sub-criterion through these fuzzy relative weights. In the second analysis stream, the fuzzy absolute weight of each sub-criterion is converted into discrete fuzzy semantic data, and the normalized responses to the questionnaires are further analyzed using Association Rule Mining to obtain the association rules among the evaluation sub-criteria.

4 Experimental Analysis

4.1 Construct the Hierarchy of Evaluation Factors

Based on the work of Parikh and Verma, the dimensions of evaluation are divided into "technology", "interface" and "function" herein [60]. Suitable evaluation criteria and sub-criteria are identified in the literature and shown in Table 2. The hierarchical structure of evaluation factors is thus constructed (in Figure 2).

Table 2. Definition of evaluation factor

Dimension	Criterion	Sub-criterion
D1 Technology	C1 Transmission quality	C1.1 Connection quality: The system connection is steady for data transmission.
		C1.2 Accuracy of data transmission: The uploaded (or downloaded) data content is correct.
	C2 System stability	C2.1 Connection stability: The frequencies of system maintain that leads user unable to connect.
		C2.2 Waiting time: The response time (such as information display and data upload) while interact with user.
		C2.3 Capacity degree of recovery: The recovery degree while system get crash.
D2 Interface	C3 Navigation	C3.1 Ease of use: The operation is intuitive without special skill. Also, the system equipped help desktop and user guideline.
		C3.2 Visualization: The layout (such as function title, text and graphic) is clear to recognize.
		C3.3 Navigation mechanism: Some assistance mechanism (such as index and search engine) enables user to locate particular resource (such as topic and web page).
	C4 Visual satisfaction	C4.1 System aesthetics: The interface (such as color and bright) is comfortable. The operation is joyful without stress.
		C4.2 Graphical arrangement of interface: The human-machine interface designs follow regular design.
	C5 System feedback	C5.1 Clear guideline and direction: The system prompt clear feedback (or response) to guide user what to do next.
		C5.2 Appropriate display system message and response: The feedback or response is appropriate and won't interrupt user operation.
D3 Function	C6 Personalization	C6.1 Personalized interface settings: The system enable user to customize the system layout according to their requirement.
		C6.2 Tracking of discussion topics: The system enable user to follow up (such as book and track) particular objects (such as topic and discussion).
	C7 Discussion functional integrality	C7.1 Integrality of discussion auxiliary tool: The system integrates with some communication tool, such as e-mail, BBS, discussion forum and online message.
		C7.2 Integrality of discussion system architecture: The function (such as reply and share) of discussion forum is completed.

Table 2. Definition of evaluation factor (continue)

Dimension	Criterion	Sub-criterion
D3 Function	C8 Interactivity	C8.1 Convenience: User can interact and communicate (such as knowledge and experience sharing) each other easily.
		C8.2 Immediateness: The update frequency of discussible forum or teaching topic.
	C9 Data statistics	C9.1 Control of learning progress: The system can generate scoring report to help user improve their learning activity.
		C9.2 Learning history: The system keep record of user's learning profile (such as learning activity and learning path).
	C10 Searching	C10.1 Course search: The system provides search mechanism.
		C10.2 Consulting on process operations: User can consult for problem solving about system operation.
	C11 Assessment of functional integrality	C11.1 Integrality of assessment method: The system provides multiple scoring mechanism for instructors to design their assessment.
		C11.2 Scoring mechanism: The scoring mechanism is completed.
	C12 User control	C12.1 User control and management of learning activities: The system enable user to arrange and control teaching schedule.
		C12.2 Management of practice and teaching materials: The e-Learning system provide tutor with the mechanism to edit, share and generate teaching material, assignment and exam.

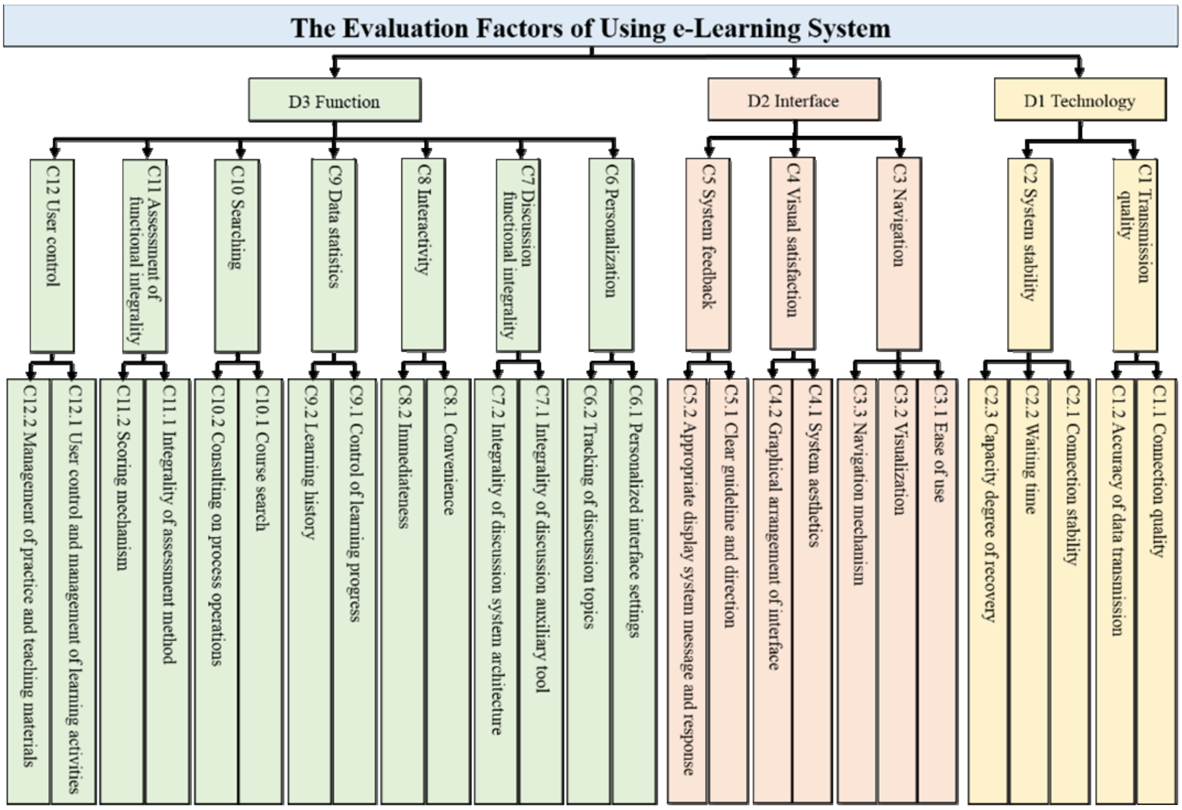

Figure 2. Hierarchical structure of evaluation factors

4.2 Distribution of Expert Questionnaire

After the hierarchical structure of evaluation factors was established, the questionnaire was distributed to experts to elicit their pairwise comparisons of factors. In this research, the instructor in the field of information technology who have practical experience of e-Learning systems were invited and conducted expert interview through face-to-face. Finally, in the two month-long experiment, field visits were made to 21 schools, and 30 expert questionnaires were delivered. Each of the questionnaires took an average of 30 minutes to complete (while the longest took at least two hours to complete). The detailed demographic information of the participants is shown in Table 3.

Table 3. Demographic of participant

Participant composition		Count
Gender	Male	21
	Female	9
Seniority	Less than 5 years	6
	5-10 years	15
	More than 10 years	9
School Properties	National university	9
	Private University	21

4.3 Consistency Test of Every Comparison

After each questionnaire had been returned, the maximum eigenvalue (λ_{max}) for each question was calculated. After λ_{max} was obtained, the consistency index *(C.I.)* and consistency ratio *(C.R.)* were calculated to evaluate the mutual consistency of the weights. *C.I.* is calculated as $(\lambda_{max} - n) / (n-1)$ and *C.R.* is calculated as *(C.I.) / (R.I.)*, where the random index *(R.I.)* proposed by Saaty and shown in Table 4, is utilized to adjust the changes of different *C.I.* values in different layers [51]. If *C.I.* and *C.R.* $\leqq 0.1$, then the consistency test is passed.

Table 4. Random consistency (R.I.) index

Number of level factors (n)	1	2	3	4	5	6	7
R.I. value	0.00	0.00	0.58	0.90	1.12	1.24	1.32

4.4 FAHP Analysis

After the consistency analysis of each expert questionnaire was checked, the FAHP method was utilized to obtain the fuzzy relative weights (RW) of each evaluation factor, which are shown in Table 5. After obtaining the fuzzy relative weight for each factor, the next step was to obtain the importance ranking of all sub-criteria. For this purpose, this study multiplied the fuzzy relative weights of the dimension layer, criterion layer and sub-criterion layer to calculate the fuzzy absolute weight (AW) for each sub-criterion in the whole hierarchical structure of evaluation factors. Since the sub-criteria under different criterion layers are different in number, when calculating the fuzzy absolute weights, the sub-criteria should be given different weight values. For example, there are three sub-criteria under the criterion C2, thus, the fuzzy absolute weights of these sub-criteria should be multiplied by 3, which is their weighted value. Finally, the critical sub-criteria were ranked in importance according to their weighted fuzzy absolute weights. The priorities for sub-criteria are shown in Table 6.

Table 5. Fuzzy relative weights of evaluation factor

Dimension	RW	Criterion	RW	Sub-criterion	RW
D1 Technology	0.273	C1 Transmission quality	0.461	C1.1 Connection quality	0.472
				C1.2 Accuracy of data transmission	0.528
		C2 System stability	0.539	C2.1 Connection stability	0.408
				C2.2 Waiting time	0.307
				C2.3 Capacity degree of recovery	0.285
D2 Interface	0.363	C3 Navigation	0.397	C3.1 Ease of use	0.390
				C3.2 Visualization	0.332
				C3.3 Navigation mechanism	0.278
		C4 Visual satisfaction	0.311	C4.1 System aesthetics	0.408
				C4.2 Graphical arrangement of interface	0.592
		C5 System feedback	0.292	C5.1 Clear guideline and direction	0.526
				C5.2 Appropriate display system message and response	0.474
D3 Function	0.364	C6 Personalization	0.149	C6.1 Personalized interface settings	0.456
				C6.2 Tracking of discussion topics	0.544
		C7 Discussion functional integrality	0.149	C7.1 Integrality of discussion auxiliary tool	0.471
				C7.2 Integrality of discussion system architecture	0.529
		C8 Interactivity	0.202	C8.1 Convenience	0.519
				C8.2 Immediateness	0.481
		C9 Data statistics	0.138	C9.1 Control of learning progress	0.507
				C9.2 Learning history	0.493
		C10 Searching	0.064	C10.1 Course search	0.485
				C10.2 Consulting on process operations	0.515
		C11 Assessment functional integrality	0.145	C11.1 Integrality of assessment method	0.551
				C11.2 Scoring mechanism	0.449
		C12 User control	0.153	C12.1 User control and management of learning activities	0.426
				C12.2 Management of practice and teaching materials	0.574

Table 6. Weighted fuzzy absolute weights and ranks of sub-criterion

Sub-criterion	Weighted AW	Normalization	Rank
C2.1 Connection stability	0.180	0.079	1
C3.1 Ease of use	0.169	0.074	2
C3.2 Visualization	0.144	0.063	3
C2.2 Waiting time	0.136	0.059	4
C4.2 Graphical arrangement of interface	0.134	0.058	5
C1.2 Accuracy of data transmission	0.133	0.058	6
C2.3 Capacity degree of recovery	0.126	0.055	7
C3.3 Navigation mechanism	0.120	0.052	8
C1.1 Connection quality	0.119	0.052	9
C5.1 Clear guideline and direction	0.111	0.049	10
C5.2 Appropriate display system message and response	0.100	0.044	11
C4.1 System aesthetics	0.092	0.040	12
C8.1 Convenience	0.076	0.033	13
C8.2 Immediateness	0.071	0.031	14
C12.2 Management of practice and teaching materials	0.064	0.028	15
C6.2 Tracking of discussion topics	0.059	0.026	16
C11.1 Integrality of assessment method	0.058	0.025	17
C7.2 Integrality of discussion system architecture	0.057	0.025	18
C9.1 Control of learning progress	0.051	0.022	19
C7.1 Integrality of discussion auxiliary tool	0.051	0.022	20
C9.2 Learning history	0.050	0.022	21
C6.1 Personalized interface settings	0.049	0.022	22
C12.1 User control and management of learning activities	0.047	0.021	23
C11.2 Scoring mechanism	0.047	0.021	24
C10.2 Consulting on process operations	0.024	0.010	25
C10.1 Course search	0.022	0.010	26

4.5 Association Rule Mining Among Sub Criteria

In this study, the Association Rule Mining is performed to analyze and to determine the relationship among evaluation sub-criteria. However, as mentioned above, the participants all used widely varying standards. Therefore, a fuzzy mechanism is used to normalize the scores of the domain experts. In addition, to implement Association Rule Mining, for each questionnaire, the fuzzy relative weight of sub-criteria (in continuous format) must be converted into the discrete fuzzy semantic data based on a numerical conversion of fuzzy semantics [61], as indicated in Table 7.

Table 7. Numerical conversion of fuzzy semantics

<table>
<tr><th>Value</th><th>Scale</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>0.077</td><td>None</td><td rowspan="6">Negligible</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.154</td><td>Very low</td><td></td><td>●</td><td></td><td>●</td></tr>
<tr><td>0.231</td><td>Low-very low</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.308</td><td>Low</td><td>●</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>0.385</td><td>Fairly low</td><td></td><td></td><td>●</td><td>●</td></tr>
<tr><td>0.462</td><td>More of less low</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.539</td><td>Medium</td><td>●</td><td>●</td><td>●</td><td>●</td><td></td></tr>
<tr><td>0.616</td><td>More of less High</td><td rowspan="2">Normal</td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.693</td><td>Fairly high</td><td></td><td></td><td></td><td>●</td></tr>
<tr><td>0.770</td><td>High</td><td>●</td><td>●</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>0.847</td><td>High-very high</td><td rowspan="3">Significant</td><td></td><td></td><td></td><td>●</td></tr>
<tr><td>0.924</td><td>Very high</td><td></td><td>●</td><td>●</td><td></td></tr>
<tr><td>1.000</td><td>Excellent</td><td></td><td></td><td></td><td></td></tr>
</table>

According to the numerical conversion of fuzzy semantics, this study adopted the scale 1 in Table 7 and divided the fuzzy relative weight of the sub-criteria from each questionnaire into three fuzzy semantics, namely, Negligible (0-0.538), Normal (0.539-0.699) and Significant (0.770-1.000). Table 8 presents an example of fuzzy semantics conversion from which one questionnaire.

Table 8. Example of fuzzy semantic conversion

Element	**C1.1**	**C1.2**	**C2.1**	**C2.2**
Weight	0.1250	0.8750	0.7986	0.0965
Semantic	Negligible	Significant	Significant	Negligible
Element	**C2.3**	**C3.1**	**C3.2**	**C3.3**
Weight	0.1049	0.7306	0.0810	0.1884
Semantic	Negligible	Normal	Negligible	Negligible
Element	**C4.1**	**C4.2**	**C5.1**	**C5.2**
Weight	0.5000	0.5000	0.1250	0.8750
Semantic	Negligible	Negligible	Negligible	Significant
Element	**C6.1**	**C6.2**	**C7.1**	**C7.2**
Weight	0.8750	0.1250	0.5000	0.5000
Semantic	Significant	Negligible	Negligible	Negligible
Element	**C8.1**	**C8.2**	**C9.1**	**C9.2**
Weight	0.8750	0.1250	0.8333	0.1667
Semantic	Significant	Negligible	Significant	Negligible
Element	**C10.1**	**C10.2**	**C11.1**	**C11.2**
Weight	0.7500	0.2500	0.7500	0.2500
Semantic	Normal	Negligible	Normal	Negligible
Element	**C12.1**	**C12.2**		
Weight	0.7500	0.2500		
Semantic	Normal	Negligible		

As converting the fuzzy relative weight of sub-criteria of each questionnaire into fuzzy semantic, this study conducted the Association Rule Mining and further obtained some meaningful rules among the sub-criteria as shown in Table 9. For example, through the Association Rule Mining indicated that the "connection stability" of e-Learning system is concerned for users, they would not care about the "Navigation mechanism" when operating system.

Table 9. Association rules among sub-criteria

Left-hand Side	Right-hand Side	Conf.
C2.3 Capacity degree of recovery (Negligible)	C1.2 Accuracy of data transmission (Significant)	1.00
C2.3 Capacity degree of recovery (Negligible)	C10.2 Consulting on process operations (Significant)	1.00
C3.3 Navigation mechanism (Negligible)	C4.2 Graphical arrangement of interface (Significant)	1.00
C3.3 Navigation mechanism (Negligible)	C10.2 Consulting on process operations (Significant)	1.00
C10.2 Consulting on process operations (Significant)	C3.3 Navigation mechanism (Negligible)	0.89
C8.1 Convenience (Significant)	C3.3 Navigation mechanism (Negligible)	0.88
C10.2 Consulting on process operations (Significant)	C2.3 Capacity degree of recovery (Negligible)	0.84
C4.2 Graphical arrangement of interface (Significant)	C3.3 Navigation mechanism (Negligible)	0.84
C2.1 Connection stability (Significant)	C3.3 Navigation mechanism (Negligible)	0.83
C1.2 Accuracy of data transmission (Significant)	C2.3 Capacity degree of recovery (Negligible)	0.82
C1.2 Accuracy of data transmission (Significant)	C3.3 Navigation mechanism (Negligible)	0.82
C1.2 Accuracy of data transmission (Significant)	C2.2 Waiting time (Negligible)	0.73

5 Conclusion and Further Work

Recently, because of promotion and resources from the domestic and the international environment, the development of e-Learning system has matured and more and more instructors and learners do online teaching or learning through these systems. Many higher education institutions in the global are looking at the e-Learning system as an effective way to assist them in managing the curriculums and teaching materials, even planning to offer online education programs through the e-Learning platform. Therefore, to understand how the users evaluate e-Learning system is an interest and important issue. For e-

Learning system evaluation, many factors can potentially affect the utility of an e-Learning system, such as the characteristics of its media, the richness of the teaching material, the system quality and others. However, for e-earning operation, the activities of instructor (including material generation and assessment design) are quite different from learner (such as material navigation). It is necessary to construct the hierarchy of evaluation factors and rank their priorities from instructor's perspective.

5.1 Academic Implications

This study makes a contribution in academia, namely, proposes a three-stage integrated systematic evaluation model that combines FAHP and Association Rule Mining and constructs a hierarchical structure for the evaluation of an e-Learning system. In the future, this evaluation model and hierarchical structure can be employed to analyze the factors considered by learners in using e-Learning systems; and the analytical results can be compared with the results from this study.

Further, the emergency of MOOCs platforms in recent years has gradually changed the mode of the traditional online learning. MOOCs have also attracted more instructors and learners to teach and learn through MOOCs platforms. However, just like the e-Learning systems, the concept of MOOCs had been introduced to the public no sooner than a surprisingly large number of MOOCs platforms emerged. Therefore, the integrated evaluation model proposed by this study can be used in the future to analyze the factors considered by users in adopting MOOCs platforms

5.2 Practical Implications

This study also has several practical implications for e-Learning users and providers. First the results of analysis herein revealed that each evaluation dimension must be considered in expert assessment. Among these dimensions, "Function" is the most important. Only mature and powerful features, and a smoother interface can satisfy the requirements of users of the e-Learning systems. Further, "Interactivity" is a very important criterion to users who are using e-Learning. A forum for interactive learning should provide a convenient platform for the real-time exchange of knowledge, and the quick updating of subject matter.

Second, with respect to the relative importance of the sub-criteria, "Connection stability", "Ease of use", "Visualization", "Waiting time" and "Graphic arrangement of interface" are the most important five sub-criteria in the evaluation of e-Learning systems. The use of an e-Learning system for online learning depends on a highly stable system connection. Also, the rapid feedbacks for users ensure that users do not have to wait for system recovery when an incorrect process operation is performed or a breakdown occurs. Furthermore, to fulfill the requirements come from both instructor and learner, an e-Learning system include diverse functions that make a complicate system architecture. Our study results match the study conducted by Zhang et al., who similarly stressed the connection quality or connection stability of the e-Learning system is an extremely important factor to instructors and learners, and the functions of the e-Learning system should be able to meet users' personal demands [62]. Further, other researchers also stressed in their researches that the interface design, the system operating guides and the ease of use of the e-Learning system are some important factors having influence on users' acceptance of e-Learning [63-65]. Their conclusions are identical to our study results. Only an e-Learning system with good system architecture and interface design can help users to access the desired functions without difficulty and take user-interested e-Learning courses to gain knowledge of interesting things. Therefore, we infer that users' acceptance of e-Learning system depends on connection stability, ease of use and visualization of the system as top three evaluation sub-criteria. According to the analysis result, we suggest that simplifying the operation of an e-Learning system and arrangement of graphics layout carefully.

Finally, some association rules (support: 0.51, confidence: 0.84) reveal that the more reasonable design of graphical arrangement of interface (significant in C4.2) implies lower requirements of Navigation mechanism (Negligible in C3.3). Therefore, the e-Learning system developer the layout of text, image and video should not be at odds with the habits of users, particular for the instructor, the customization mechanism allowing them to setup up the environment would be helpfulness.

The analysis results of this study have been verified and can be referred by both instructor and system developer. For instructors that intend to involve themselves in e-Learning teaching, the evaluate factors help them to compare and locate feasible e-Learning system rapidly. On the other hand, for a developer of an e-Learning system, they can improve user experience using these factors and their priorities accordingly.

References

[1] D. Zhang, J.-L. Zhao, L. Zhou, J.-F. Nunamaker Jr., Can E-Learning Replace Classroom Learning? *Communications of the ACM*, Vol. 47, No. 5, pp. 75-79, May, 2004.

[2] R. C. Clark, R. E. Mayer, *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*, John Wiley & Sons, 2011.

[3] S.-S. Liaw, H.-M. Huang, G.-D. Chen, Surveying Instructor and Learner Attitudes toward E-Learning, *Computers & Education*, Vol. 49, No. 4, pp. 1066-1080, December, 2007.

[4] T. Phan, S.-G. McNeil, B.-R. Robin, Students' Patterns of

Engagement and Course Performance in a Massive Open Online Course, *Computers & Education*, Vol. 95, pp. 36-44, April, 2016.

[5] C.-C. Kao, P.-S. Chiu, T.-S. Chen, T.-W. Hou, AHP-based Evaluation Model for Context-Aware Mobile Learning System, *Journal of Internet Technology*, Vol. 16, No. 2, pp. 267-275, March, 2015.

[6] P.-C. Chen, T.-S. Lan, S.-C. Chiu, Y.-H. Lan, A Study of Investigating the Learning Effectiveness of Applying the MOODLE E-Learning in Taiwan, *Journal of Internet Technology*, Vol. 15, No. 7, pp. 1191-1194, December, 2014

[7] W. Huang, Z.-X. Lin, J.-H. Huang, How to Compete in a Global Education Market Effectively: A Conceptual Framework for, in: F. Tan, M. G. Hunter (Eds.), *Advanced Topics in Global Information Management*, Vol. 4, Idea Group, 2005, pp. 91-115.

[8] N. Liu, X. Yang, H.-C. Chan, Exploring the Antecedents to Learning Continuance in Virtual Worlds: A Balanced Thinking-Feeling and Social-Constructivism Perspective, *Journal of Global Information Management*, Vol. 21, No. 2, pp. 1-22, April-June, 2013.

[9] H.-C. Lucas, Can the Current Model of Higher Education Survive MOOCs and Online Learning? *Educause Review*, Vol. 48, No. 5, pp. 54-66, September, 2013.

[10] D. Zhang, L. Zhou, R.-O. Briggs, J.-F. Nunamaker Jr., Instructional Video in e-Learning: Assessing the Impact of Interactive Video on Learning Effectiveness, *Information & Management*, Vol. 43, No. 1, pp. 15-27, January, 2006.

[11] D. Zhan, Interactive Multimedia-based E-Learning: A Study of Effectiveness, *The American Journal of Distance Education*, Vol. 19, No. 3, pp. 149-162, June, 2005.

[12] Y.-S. Yan, P.-J. Chuang, C.-Y. Huang, T.-W. Hou, C.-S. Yang, An Efficient Adaptive Fuzzy Learn in Diagnosis Method for e-Learning, *Journal of Internet Technology*, Vol. 16, No. 3, pp. 391-401, May, 2015.

[13] S. Peter, W. DeLone, E. McLean, Measuring Information Systems Success: Models, Dimensions, Measures, and Interrelationships, *European Journal of Information Systems*, Vol. 17, No, 3, pp. 236-263, July, 2008.

[14] W.-H. DeLone, E.R. McLean, Information Systems Success: The Quest for the Dependent Variable, *Information systems research*, Vol. 3, No, 1, pp. 60-95, March, 1992.

[15] K.-A. Al-Busaidi, An Empirical Investigation Linking Learners' Adoption of Blended Learning to Their Intention Of Full e-Learning, *Behaviour & Information Technology*, Vol. 32, No. 11, pp. 1168-1176, April, 2013.

[16] O. Petit dit Dariel, H. Wharrad, R. Windle, Exploring the Underlying Factors Influencing e-Learning Adoption in Nurse Education, *Journal of Advanced Nursing*, Vol. 69, No. 6, pp. 1289-1300, June, 2013.

[17] S.-H. Purnomo, Y.-H. Lee, E-Learning Adoption in the Banking Workplace in Indonesia an Empirical Study, *Information Development*, Vol. 29, No. 2, pp. 138-153, July, 2012.

[18] G. Capece, D. Campisi, User Satisfaction Affecting the Acceptance of an e-Learning System as a Mean for the Development of the Human Capital, *Behaviour & Information Technology*, Vol. 32, No. 4, pp. 335-343, July, 2013.

[19] J.-J. Torres-Gordillo, D. Cobos-Sanchiz, Assessment of Participants' Satisfaction with e-Learning: A Study on Risk Prevention and Environment Training, *Culture and Education*, Vol. 25, No. 1, pp. 109-122, January, 2013.

[20] T.-R. Liyanagunawardena, A.-A. Adams, S.-A. Williams, MOOCs: A Systematic Study of the Published Literature 2008-2012, *The International Review of Research in Open and Distributed Learning*, Vol. 14, No. 3, pp. 202-227, November, 2013.

[21] G. Veletsianos, P. Shepherdson, A Systematic Analysis and Synthesis of the Empirical MOOC Literature Published in 2013-2015, *The International Review of Research in Open and Distributed Learning*, Vol. 17, No. 2, pp. 198-221, February, 2016.

[22] D. Gasevic, V. Kovanovic, S. Joksimovic, G. Siemens, Where is Research on Massive Open Online Courses Headed? A Data Analysis of the MOOC Research Initiative, *The International Review of Research in Open and Distributed Learning*, Vol. 15, No. 5, pp. 134-176, November, 2014.

[23] J. DeBoer, G.-S. Stump, D. Seaton, A. Ho, D.-E. Pritchard, L. Breslow, Bringing Student Backgrounds Online: MOOC User Demographics, Site Usage, and Online Learning, T*he 6th International Conference on Educational Data Mining (EDM 2013)*, Memphis, Tennessee, USA, 2013, pp. 312-313.

[24] J.-C. Roca, C.-M. Chiu, F.-J. Martínez, Understanding e-Learning Continuance Intention: An Extension of the Technology Acceptance Model. *International Journal of Human-Computer Studies*, Vol. 64, No. 8, pp. 683-696, August, 2006.

[25] M.-M. Terras, J. Ramsay, Massive Open Online Courses (Moocs): Insights and Challenges from a Psychological Perspective, *British Journal of Educational Technology*, Vol. 46, No. 3, pp. 472-487, April, 2015.

[26] T. Teo, Preservice Teachers' Satisfaction with e-Learning, *Social Behavior and Personality: An International Journal*, Vol. 42, No. 1, pp. 3-6, February, 2014.

[27] E.-T. Welsh, C.-R. Wanberg, K.-G. Brown, M.-J. Simmering, E-learning: Emerging Uses, Empirical Results and Future Directions, *International Journal of Training and Development*, Vol. 7, No. 4, pp. 245-258, November, 2003.

[28] D.-H. Jonassen, *Applications and Limitations of Hypertext Technology for Distance Learning*, Armstrong Laboratory, 1992.

[29] C. Costa, H. Alvelos, L. Teixeira, The Use of Moodle e-Learning Platform: A Study in a Portuguese University, *Procedia Technology*, Vol. 5, pp. 334-343, September, 2012.

[30] I. Novo-Corti, L. Varela-Candamio, M. Ramil-DíAz, E-Learning and Face to Face Mixed Methodology: Evaluating Effectiveness of e-Learning and Perceived Satisfaction for a Microeconomic Course Using the Moodle Platform, *Computers in Human Behavior*, Vol. 29, No. 2, pp. 410-415, March, 2013.

[31] H.-D. Surjono, The Evaluation of a Moodle Based Adaptive

e-Learning System, *International Journal of Information and Education Technology*, Vol. 4, No. 1, pp. 89-92, February, 2014.

[32] L. Umek, A. Aristovnik, N. Tomaževič, D. Keržič, Analysis of Selected Aspects of Students' Performance and Satisfaction in a Moodle-based e-Learning System Environment, *Eurasia Journal of Mathematics, Science & Technology Education*, Vol. 11, No. 6, pp. 1495-1505, June, 2015.

[33] C. Katsanos, N. Tselios, M. Xenos, Perceived Usability Evaluation of Learning Management Systems: A First Step towards Standardization of the System Usability Scale in Greek, *16th Panhellenic Conference on Informatics with international participation (PCI 2012)*, Piraeus, Greece, 2012, pp. 302-307.

[34] J. Ismail, The Design of an e-Learning System: Beyond the Hype, *Internet and Higher Education*, Vol. 4, No. 3-4, pp. 329-336, February, 2002.

[35] C. Danielson, T.-L. McGreal, *Teacher Evaluation to Enhance Professional Practice*, ASCD, 2000.

[36] M.-J. Rosenberg, *E-Learning: Strategies for Delivering Knowledge in the Digital Age*, McGraw Hill, 2001.

[37] C. Aldrich, *Simulations and the Future of Learning: An Innovative (and perhaps revolutionary) Approach to e-Learning*, John Wiley & Sons, 2004.

[38] G.-J. Hwang, T.-C.-K. Huang, J.-C.-R. Tseng, A Group-decision Approach for Evaluating Educational Web Sites, *Computers & Education*, Vol. 42, No. 1, pp. 65-86, January, 2004.

[39] S.-S. Liaw, Investigating Students' Perceived Satisfaction, Behavioral Intention, and Effectiveness of e-Learning: A Case Study of the Blackboard System, *Computers & education*, Vol. 51, No. 2, pp. 864-873, September, 2008.

[40] W.-S. Lin, C.-H. Wang, Antecedences to Continued Intentions of Adopting e-Learning System in Blended Learning Instruction: A Contingency Framework Based on Models of Information System Success and Task-Technology Fit, *Computers & Education*, Vol. 58, No. 1, pp. 88-99, January, 2012.

[41] S.-Y. Park, An Analysis of The Technology Acceptance Model in Understanding University Students' Behavioral Intention to Use e-Learning, *Journal of Educational Technology & Society*, Vol. 12, No. 3, pp. 150-162, July, 2009.

[42] C.-M. Chiu, M.-H. Hsu, S.-Y. Sun, T.-C. Lin, P.-C. Sun, Usability, Quality, Value and e-Learning Continuance Decisions, *Computers & Education*, Vol. 45, No. 4, pp. 399-416, December, 2005.

[43] Y.-S. Wang, H.-Y. Wang, D.-Y. Shee, Measuring e-Learning Systems Success in an Organizational Context: Scale Development and Validation, *Computers in Human Behavior*, Vol. 23, No. 4, pp. 1792-1808, July, 2007.

[44] T.-L. Saaty, A Scaling Method for Priorities in Hierarchical Structures, *Journal of Mathematical Psychology*, Vol. 15, No. 3, pp. 234-281, June, 1977.

[45] B. Golden, E. Wasil, P. Harker, *The Analytic Hierarchy Process: Applications and Studies*, Springer-Verlag, 1989.

[46] T.-L. Saaty, *The Analytic Hierarchy Process: Planning, Priority Setting, Resources Allocation*, McGraw Hill, 1980.

[47] F.-T. Chan, N. Kumar, Global Supplier Development Considering Risk Factors Using Fuzzy Extended AHP Approach, *Omega*, Vol. 35, No. 4, pp. 417-431, August, 2007.

[48] A.-H. Lee, W.-C. Chen, C.-J. Chang, A Fuzzy AHP and BSC Approach for Evaluating Performance of IT Department in the Manufacturing Industry in Taiwan, *Expert Systems with Applications*, Vol. 34, No. 1, pp. 96-107, January, 2008.

[49] P.-J.-M. Van Laarhoven, W. Pedrycz, A Fuzzy Extension of Saaty's Priority Theory, *Fuzzy Sets and Systems*, Vol. 11, No. 1, pp. 199-227, January, 1983.

[50] J.-J. Buckley, Fuzzy Hierarchical Analysis, *Fuzzy Sets and Systems*, Vol. 17, No. 3, pp. 233-247, December, 1985.

[51] S.-L. Lin, C.-S. Wang, Integration of FAHP and Association Rule to Establish the Evaluation Mechanism for e-Learning Platform, *Journal of Management & Systems*, Vol. 22, No. 1, pp. 125-147, January, 2015.

[52] M. Jami Pour, M. Hosseinzadeh, M. Bagherzadeh Azar, F. Taheri, Developing a New Framework for Evaluating E-Learning Systems: Integrating BSC and FAHP, *Kybernetes*, Vol. 46, No. 8, pp. 1303-1324, February, 2017.

[53] T.-L. Saaty, Decision Making with the Analytic Hierarchy Process, *International Journal of Services Sciences*, Vol. 1, No. 1, pp. 83-98, January, 2008.

[54] T.-Y. Hsieh, S.-T. Lu, G.-H. Tzeng, Fuzzy MCDM Approach for Planning and Design Tenders Selection in Public Office Buildings, *International Journal of Project Management*, Vol. 22, No. 7, pp. 573-584, October, 2004.

[55] H.-K. Chiou, G.-H. Tzeng, Fuzzy Hierarchical Evaluation with Grey Relation Model of Green Engineering for Industry, *International Journal of Fuzzy Systems*, Vol. 3, No. 3, pp. 466-475, January, 2001.

[56] D.-L. Mon, C.-H. Cheng, J.-C. Lin, Evaluating Weapon System Using Fuzzy Analytic Hierarchy Process Based on Entropy Weight, *Fuzzy Sets and Systems*, Vol. 62, No. 2, pp. 127-134, March, 1994.

[57] S. Kubler, J. Robert, W. Derigent, A. Voisin, Y. Le Traon, A State-of the-Art Survey & Testbed of Fuzzy AHP (FAHP) Applications, *Expert Systems with Applications*, Vol. 65, pp. 398-422, December, 2016.

[58] R. Agrawal, R. Srikant, Fast Algorithms for Mining Association Rules, *20th International Conference on Very Large Data Bases (VLDB 1994)*, San Francisco, CA, USA, 1994, pp. 487-499.

[59] T.-L. Saaty, How to Make a Decision: The Analytic Hierarchy Process, *European Journal of Operational Research*, Vol. 48, No. 1, pp. 9-26, September, 1990.

[60] M. Parikh, S. Verma, Utilizing Internet Technologies to Support Learning: An Empirical Analysis, *International Journal of Information Management*, Vol. 22, No. 1, pp. 27-46, February, 2002.

[61] S.-J. Chen, C.-L. Hwang, *Fuzzy Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, 1992.

[62] L. Zhang, H. Wen, D. Li, Z. Fu, S. Cui, E-Learning Adoption

Intention and its Key Influence Factors Based on Innovation adoption theory, *Mathematical and Computer Modelling*, Vol. 51, No. 11-12, pp. 1428-1432, June, 2010.
[63] F. Calisir, C. Altin Gumussoy, A.-E. Bayraktaroglu, D. Karaali, Predicting the Intention to Use a Web-based Learning System: Perceived Content Quality, Anxiety, Perceived System Quality, Image, and the Technology Acceptance Model, *Human Factors and Ergonomics in Manufacturing & Service Industries*, Vol. 24, No. 5, pp. 515-531, August, 2014.
[64] M. Nilashi, N. Janahmadi, Assessing and Prioritizing Affecting Factors in e-Learning Websites Using AHP Method and Fuzzy Approach, *Information and Knowledge Management*, Vol. 2, No. 1, pp. 46-61, January, 2012.
[65] D.-Y. Shee, Y.-S. Wang, Multi-criteria Evaluation of the Web-based e-Learning System: A Methodology Based on Learner Satisfaction and Its Applications, *Computers & Education*, Vol. 50, No. 3, pp. 894-905, April, 2008.

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