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Quality evaluation for multimedia contents of e-learning systems using the ANP approach on high speed network

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Abstract
E-learning systems have played an important role in the education field and have been widely employed in many educational institutions. Although the need to evaluate the quality of e-learning systems is emerging, there is currently no appropriate evaluation method due to the complicated correlations between quality attributes. This study develops a quality evaluation model that calculates the priority weights of each quality attribute while accounting for their correlations and evaluates the overall quality of a learning system with numerical results. First, the study constructs a quality attribute network that reflects the correlations between 4 main quality clusters and 19 sub-attributes. Second, it calculates the priority weights of the attributes using the Analytic Network Process (ANP). Finally, using the quality network and weights, this study evaluates three types of e-learning systems employed by Kyunghee Cyber University. The results indicate that the proposed evaluation method provides a mechanism for objectively analyzing and comparing the qualities of various kinds of learning systems and suggests guidelines for constructors and managers of learning systems.

Keywords ANP · E-learning system · System quality attribute · Quality evaluation model · QoS for learning system

1 Introduction

Because e-learning systems, a subset of e-learning systems, play an important role in learning performance, many higher education institutions have implemented them. In particular,

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Kyunghee Cyber University in Korea operates a regular undergraduate curriculum through e-learning systems. Course websites of e-learning systems provide online learning materials that supplement traditional classroom instruction; as well as online communication tools, such as e-mail, discussion boards, and document sharing systems, which facilitate user-to-user and user-to-instructor interactions and negotiations. Because e-learning systems are of increasing importance in the instructional process, assessments of their effectiveness and quality are critical for both educators and researchers.

The success of e-learning systems depends largely on user satisfaction and other factors that increase users' desire for and commitment to continued use of the systems (continuance intention) [9]. To evaluate the quality of e-learning systems with respect to user satisfaction, previous researchers have applied the DeLone and McLean model [13, 14], which evaluates the quality of information systems. However, while this model identifies factors that influence the quality of e-learning systems, it does not consider the degree of influence of each factor. To evaluate the relative importance of quality factors, Lin [25] applied a fuzzy Analytic Hierarchy Process (AHP) approach to determine the relative weights of course website quality factors between high and low online learning experience groups.

Because quality evaluation is a very complex process affected by a multitude of interrelated variables, the approaches of both the DeLone and McLean model [2, 33] and the Lin model are insufficient to objectively evaluate and compare the various kinds of learning systems because they fail to reflect correlations between the quality attributes that make up the overall quality of a learning system.

In this study, we extracted the quality attributes that determine the user satisfaction quality of e-learning systems. Next, we suggested a quality evaluation process that will provide more accurate and objective evaluations by applying the Analytic Network Process (ANP) [5, 22] to calculate the weights of each quality attribute with consideration for the correlations between them. This process enables users to compare the qualities of e-learning systems objectively and recommends guidelines for quality attributes that developers and instructors can use to increase the overall quality of their e-learning systems.

In the next section, we review previous research on quality evaluations of e-learning systems. Section 3 briefly explains ANP, and Section 4 details the proposed evaluation process. In Section 5, we present the evaluation results of Kyunghee Cyber University's e-learning systems, and conclusions are drawn in Section 6.

2 Related research

This section briefly explains the concepts behind e-learning systems and outlines previous attempts to evaluate the quality of e-learning systems.

2.1 E-learning systems

Gunasekaran, McNeil, and Shaul [16] described e-learning, also known as e-learning, as a learning process in which web-enabled technologies are used to encourage interaction and communication between students and instructors. Ngai et al. [28] stated that e-learning systems serve as a platform to facilitate teaching and learning and provide new approaches to conducting classes and delivering course materials. The Institute of Electrical and Electronics Engineers (IEEE) Learning Technology Standard Committee defined an e-learning system as "a learning technology system that uses Web-browsers as the primary means of interaction with learners, and the Internet or an intranet as the primary means of communication among its subsystems and with other systems" [28]. Thus, it has been argued that any e-learning system that enables interaction and communication between instructors and students by means of various networking technologies can be classified as an e-learning system [40].

These e-learning systems play an important role in learning performance [47], and many institutions of higher education, such as Kyunghee Cyber University in Korea, have implemented them as a primary means of education.

In another recent step forward, with the expansion of network technology, various types of mobile learning [1, 15, 21] and ubiquitous learning systems [42, 44] are being proposed. As the use of various network-based learning systems expands, the need increases for an evaluation method that can be objectively applied to various types of learning systems and used to develop guidelines for their improvement.

In this paper, we constructed the quality attribute matrix and applied it to a quality evaluation of a e-learning system, but by modifying the quality attribute matrix, the proposed evaluation process can be applied to ubiquitous and mobile learning systems.

2.2 Quality evaluation methods for e-learning systems

The DeLone and McLean [13] model is one of the most widely cited Information System (IS) success models [18, 27]. This model suggests that a systematic combination of individual measures from IS success categories can create a comprehensive measurement instrument. DeLone and McLean have updated their model [14] and evaluated its usefulness in light of the dramatic changes in IS practice, particularly the emergence and explosive growth of internet-based applications. This model of quality attributes consists of six dimensions: system quality, information quality, service quality, intention to use/use, user satisfaction, and net benefit.

An e-learning system is a special type of IS. The DeLone and McLean [14] updated model can be adapted to the measurement challenges of an e-learning system [41]. In addition, many other studies have investigated quality attributes to analyze and develop advanced e-learning systems. To design an effective e-learning environment, Anita [24] suggested three considerations for system design: system quality, information quality, and service quality. Each of these criteria is found in the DeLone and McLean [14] model as well. Samantha and Alexei [36] and T. Ramayah et al. [31] suggested three criteria, content quality, system quality, and service quality, as the main factors affecting a learner's satisfaction with an e-learning system, and Halonen et al. [17] implemented a success model using the DeLone and McLean [14] model for evaluating an e-learning system's environment.

However, these methods do not adequately reflect the degree of influence each quality attribute has on the overall quality of an e-learning system. They fail to acknowledge that each quality attribute affects the overall quality of the system to a different degree, which is referred to as weight.

To evaluate the quality of an e-learning system in a way that considers the weight of each quality attribute, the AHP was introduced. The AHP is a multi-criteria decision making method [34] and is primarily used to solve problems involving comparisons of multiple criteria [8]. Zhang et al. [46] analyzed the influence factors of e-learning system adoption on Chinese undergraduates using the AHP. Chao and Chen [8] proposed a method that employed the AHP model to weight the factors in an e-learning system and evaluate the overall e-learning effectiveness.

Lin [25] proposed a hierarchical structure model that considers the characteristics of an e-learning system based on the DeLone and McLean [14] model. The Lin model addressed the system via four factors, system quality, information quality, service quality, and attractiveness, and applied a fuzzy AHP approach to evaluate the relative importance of each of the quality factors.

E. Herrera-Viedma et al. [19] devised a user-driven evaluation scheme to evaluate the information quality of content-based web sites, which calculates weights and evaluates qualities from a user's linguistic evaluation judgments through the application of Fuzzy Computing with words.

Vincenza et al. [6] proposed the reliability of resources for users as a criterion for evaluating e-learning. The users evaluate whether e-learning contents can be recommended as useful and the reliability of peers, that is, whether it is possible to trust them as providers. They proposed integrating these concepts into e-learning systems, introducing a model for searching for personalized and useful learning paths suggested by reliable (trusted) peers. Ja-Hwung et al. [38] proposed a novel recommender, namely FRSA (Fusion of Rough-Set and Average-category-rating), which integrates multiple contents and collaborative information to predict users' preferences based on the fusion of Rough-Set and Average-category-rating. Through the integrated mining of multiple contents and collaborative information, they tried to reduce the gap between the user's preferences and the automated recommendations. However, these studies focused mainly on quality of learning contents.

Mona Alkhattabi et al. [3] suggested an information quality evaluation method in e-learning systems based on the quality framework that consists of 14 quality dimensions grouped in three quality factors: intrinsic, contextual representation and accessibility. They used the relative importance by correlation analysis as a weight of quality parameter. However, they constructed the quality framework as a hierarchy structure without considering interrelations.

These previous studies considered the weight of quality attributes in quality evaluations but did not analyze the interrelations between quality attributes or reflect on the weight calculation. Because quality attributes in software affect each other and determine the overall quality of the software based on the correlations between them, objective analyses and evaluations of the weights of each attribute require that these correlations be taken into account. Previous studies, including the AHP model, are sufficient to analyze the relations between each quality attribute as a hierarchy structure but are limited in their abilities to consider correlations as a network.

In this paper, we construct a network of quality attributes based on the correlations between them and analyze the network using the ANP. As a result of this analysis, we obtain the weights of each quality attribute that reflect the correlations and apply the weights to evaluate the e-learning systems of Kyunghee Cyber University.

Table 1 shows a comparison of the main characteristics for the DeLone and McLean model [14], Lin's model (Fuzzy AHP) [25], and the applied ANP.

In the next section, we review the ANP briefly.

Table 1 Comparison of previous e-learning system quality evaluation models and ANP

Categories	D&M Model	Lin's Model (Fuzzy AHP)	ANP
Priority weights of attributes	Not considered	Considered	Considered
Correlations between attributes	Not considered	Not considered	Considered
Quality attributes cluster	Constructed	Constructed	Constructed
Overall quality evaluation by each attribute	Partially considered	Considered	Considered

3 Analytic network process

Many decision problems cannot be classified as hierarchical because of dependencies (inner/outer) and influences across and within clusters. The ANP is very useful in solving these kinds of problems. It provides a general framework with which to handle decisions without making assumptions about the independence of higher level elements from lower level elements and of the elements within a level. In fact, the ANP uses a network that does not need to specify levels as in a hierarchy. The ANP was first introduced by Saaty, based on a 1 to 9 scale, in his book, "The Analytic Hierarchy Process" [34].

Saaty suggested using the AHP to solve the problem of independence of alternatives or criteria and using the ANP to solve the problem of dependence among alternatives or criteria. The structural difference between the AHP (hierarchy) and ANP (network) is also shown in Fig. 1. As the figure shows, a hierarchy is a simpler form of a network.

Nodes of the network represent components of the system; arcs denote interactions between them. To build the decision problem, all of the interactions among the elements should be considered. As Fig. 1b shows, X → Y means that the elements of a component Y depend on component X.

Therefore, to apply the ANP, first, the system should be stated clearly and decomposed into a rational system, such as a network [11]. The structure can be obtained from the opinions of decision makers through brainstorming or other appropriate methods.

In the second step, decision elements at each component are compared pairwise with respect to their importance to their control criteria, and the components themselves are also compared pairwise with respect to their contributions to the overall goal. Decision makers are asked to respond to a series of pairwise comparisons in which two elements or two components at a time are compared in terms of how they contribute to their particular upper level criteria. In addition, if there are interdependencies among elements of a component, additional pairwise comparisons need to be created, and an eigenvector can be obtained for each element to show the influence of other elements on it. The relative importance values are determined with Saaty's 1 to 9 scales in Table 2 [35].

A reciprocal value is assigned to the inverse comparison; that is, $aij = 1 / aji$, where aij (aji) denotes the relative importance of the ith (jth) element with respect to the jth (ith) element. Pairwise comparison in ANP is made in the framework of a matrix, and a local priority vector

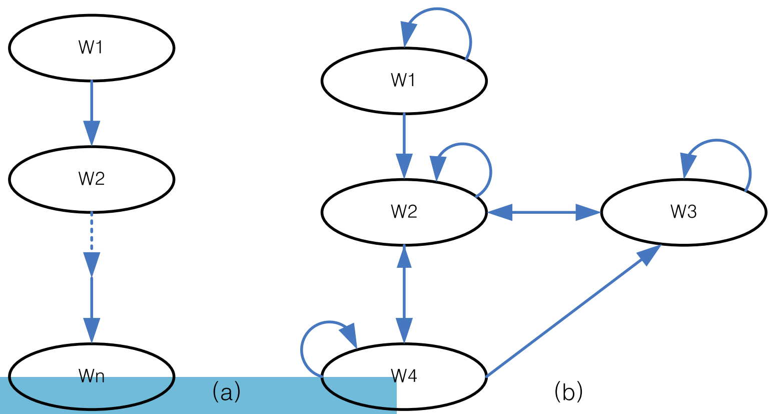


Fig. 1 **a** Hierarchy structure, **b** Network structure

can be derived as an estimate of relative importance associated with the elements (or components) being compared by solving the following equation:

$$A \times w = \lambda_{max} \times w \tag{1}$$

where A is the matrix of pairwise comparison, w is the eigenvector, and λ_{max} is the largest eigenvalue of A. To calculate the eigenvector, we used mathematical programs like Excel and Matlab 7.1.

To obtain global priorities or weights in a system with interdependent influences, the local priority vectors are entered into the appropriate columns of a matrix. As a result, the supermatrix is actually a partitioned matrix in which each matrix segment represents a relationship between two nodes (components or clusters) in a system [26]. The local priority vectors obtained are grouped and located in appropriate positions in a supermatrix based on the flow of influence from one component to another or from a component to itself, as in the loop. A sample form of the supermatrix of Fig. 1b is demonstrated in Eq. (2) [35].

$$A = \begin{bmatrix} W_{11} & 0 & 0 & 0 \\ W_{21} & W_{22} & W_{23} & W_{24} \\ 0 & W_{32} & W_{33} & W_{34} \\ 0 & W_{42} & 0 & W_{44} \end{bmatrix} \tag{2}$$

In the supermatrix, W_{21}, W_{22}, W_{23}, W_{24}, W_{32}, W_{33}, W_{34}, W_{42}, and W_{44} show the sub-matrices. In addition, the clusters, which have no interaction, are shown in the supermatrix with zero (0). In the supermatrix, W_{21} means that cluster 2 depends on cluster 1.

Over the years, ANP has been widely used in solving many complicated decision problems between multiple alternatives. In recent papers, Ihsan Yuksel [45] used ANP in SWOT analysis of a textile firm, and Che-Wei Chang et al. [7] applied ANP to digital video recorder system evaluation. Additionally, the process was applied to the selection of R&D projects [23] and photovoltaic solar power plant investment projects [4].

In this paper, we applied the ANP to determine the weights of the quality attributes of e-learning systems. In Section 4, we explain the process in detail.

4 Determining weights of quality attributes for multimedia contents in e-learning systems

In this section, we extract the quality attributes that determine the overall quality of an e-learning system and construct a quality attribute network containing correlations between the

Table 2 Saaty's 1 to 9 scales for ANP preference

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the object
3	Moderate importance	Experience and judgment slightly favor one over the other
5	Strong importance	Experience and judgment strongly favor one over the other
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over the other is affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromises between the priorities listed above

attributes. The ANP is performed based on the constructed network, and the weights of each attribute in the overall quality of the system are calculated.

An overall evaluation process is shown in Fig. 2. As shown in steps 1-4 of the process, an expert group carried out the tasks required, and based on previous results, users evaluated a system at step 6. It was necessary to extract the related quality attributes, organize the quality clusters, construct the attribute network, and perform the pairwise comparison on the network. Therefore, in this study, we organized an expert group. The expert group reviewed the draft we proposed for Steps 1 through 4 in Fig. 2 and made suggestions about how to supplement the draft. We repeated this process until the expert group decided that the attribute group and network were sufficient to proceed to the next step. Additionally, pairwise comparisons for the quality attributes based on the network were performed by the expert group, and we constructed the pairwise comparison matrix using the average values from each pairwise comparison matrix of the experts.

Technical profiles of twenty participants in the expert group of this study were balanced between e-learning system constructors (30.00%), software system engineers (30.00%), instructors at Kyunghee Cyber University who use e-learning systems (20.00%), and educators and research staff (20.00%). Most of the participants had more than five years of experience in their positions (90.00%), and with regard to their professional qualifications related to e-learning systems or software products, they had high levels of experience using this kind of product. Additionally, enrolled students in the university took part in verifying the attributes in Table 3 and the attribute network and the ANP analysis in this section.

4.1 Extracting multimedia quality attributes of e-learning systems

To extract the quality attributes of e-learning systems, we built on the DeLone and McLean [14] and Lin models [25]. In evaluations of the qualities of learning systems, the DeLone and McLean [14] model has been widely used due to its comprehensiveness, but it is insufficient in

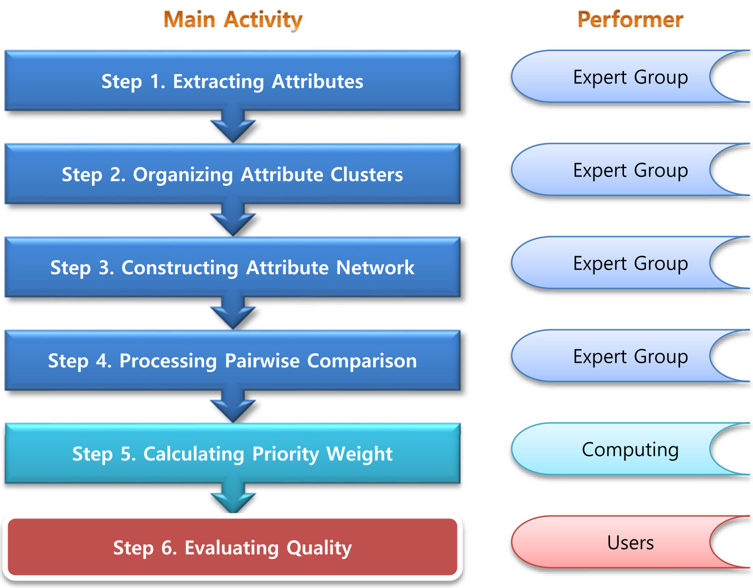


Fig. 2 Proposed e-learning system quality evaluation process

Table 3 Quality attributes of an e-learning system

Cluster	*Sub-attribute*	*Description*
System quality (SYSQ)	Accessibility (AB)	The degree to which web resources, learning materials, services, and environments are accessible by as many learners as possible [25].
	Response time (RT)	The degree to which an e-learning system offers a quick (or timely) response to requests for information or action [25, 43]
	Easy-to-use (EU)	The degree to which an e-learning system is simple to understand and operates easily.
	Stability (ST)	The degree to which the system is consistently stable and able to support processes without system errors.
	User friendly (UF)	The quality of user experience across the e-learning system, learning materials and environments, and the ability to interact with the system.
Information quality (INFQ)	Accuracy (AC)	Represents both actual correctness and learner perceptions of the correctness of information.
	Currency (CU)	The degree to which information is up-to-date and precisely reflects the current state of the world that it represents [25].
	Completeness (CO)	The degree to which the e-learning system provides all necessary information [25, 40] without construction errors in learning contents.
	Format (FM)	Learner perceptions of how effectively the information is presented [43] and constructed on the webpage.
Service quality (SERQ)	Reliability (RE)	The degree to which the e-learning service can be trusted to dependably and accurately perform a promised service [25, 37].
	Responsiveness (RS)	How often an e-learning system provides services (e.g., responses to learner inquiries, information retrieval and rapid navigation speed) that are important to its users [25].
	Available (AV)	The degree to which the e-learning service is ready for immediate use.
	Navigability (NA)	How easily the e-learning service can be found by users on the Web.
	Empathy (EM)	Whether the service involves individualized attention, such as personal thank you notes from course websites, and the availability of a message area for learner questions or comments [25].
Attractiveness (ATTR)	Multimedia capability (MC)	The use of multimedia features (e.g., text, graphics, video clips, audio clips, and animation) to present learning materials in a manner that enhances learner preferences for e-learning systems [25].
	Webpage design (WD)	The sophistication of design and attractiveness and organization of the appearance of an e-learning system [25].
	Course design (CD)	The designs of appropriate e-learning scenarios, including course title, type and modality. E-learning course design should provide appropriate learning scenarios to facilitate student-to-student and student-to-instructor communications [25].
	Enjoyment (EN)	The degree to which the learner enjoys using the e-learning system [25]. Many e-learning systems support interesting factors using the various multimedia materials to succeed in this category.

Table 3 (continued)

Cluster	*Sub-attribute*	*Description*
	Learnability (LA)	The ease with which learners can effectively interact with the e-learning system and then attain a maximal level of performance. Learnability enables learners to accomplish their course tasks and thus may increase user satisfaction levels and positive mood [25].

its representation of the overall quality characteristics of e-learning systems because it focuses only on system quality, information quality and service quality, or the main aspects of system design. Subsequently, Lin's model [25] modified six dimensions of the DeLone and McLean [14] model to reflect the quality characteristics of learning systems and suggested four quality clusters: system quality, information quality, service quality, and attractiveness.

In this paper, based mainly on previous studies mentioned in section 2-2 and Lin's model [25], we constructed four quality clusters together with their sub-attributes, which are measured in the quality attribute hierarchy (see Table 3), and they were verified by the expert group. For the proposed quality decision model of e-learning systems, a total of 19 sub-attributes are determined under the 4 main quality clusters: System quality, Information quality, Service quality and Attractiveness. The main quality clusters are defined as follows:

- *System quality*: This quality cluster refers to the perceived ability of an e-learning system to provide suitable functions in relation to learner control.
- *Information quality*: This quality cluster refers to the quality of the information provided by the e-learning systems. The presentation of information regarding learning contents, subjects and items is the fundamental capability of learning systems [24].
- *Service quality*: This quality cluster refers to the desirable characteristics of student-instructor interactions [24] and measures the overall support delivered by the learning system [10, 25].
- *Attractiveness*: This quality cluster refers to the degree of user belief that e-learning pages are fun to read and visually pleasing. Graphic design, layout, and content can improve e-learning page aesthetics and visual attractiveness [25, 32].

Table 3 defines this model's sub-attributes. All of the clusters and sub-attributes of each cluster are given a code letter. These codes will be used in the network and the supermatrix.

Because the authors' and expert group's fields of specialization do not include pedagogy, the quality evaluation demonstrated next is focused on a platform of the learning system rather than its contents.

4.2 Determining the weights of the quality attributes using the ANP

The network model of clusters and sub-attributes constructed to evaluate the quality of e-learning systems is presented in Fig. 3. It shows that each cluster and sub-attribute affects the others both within and across clusters.

The dotted arrows represent the correlations and the directions of influences between sub-attributes within the same attribute cluster. For example, *Accessibility* in the *System quality* cluster is affected by the *User friendly, Response time, Easy-to-use,* and *Stability* sub-attributes.

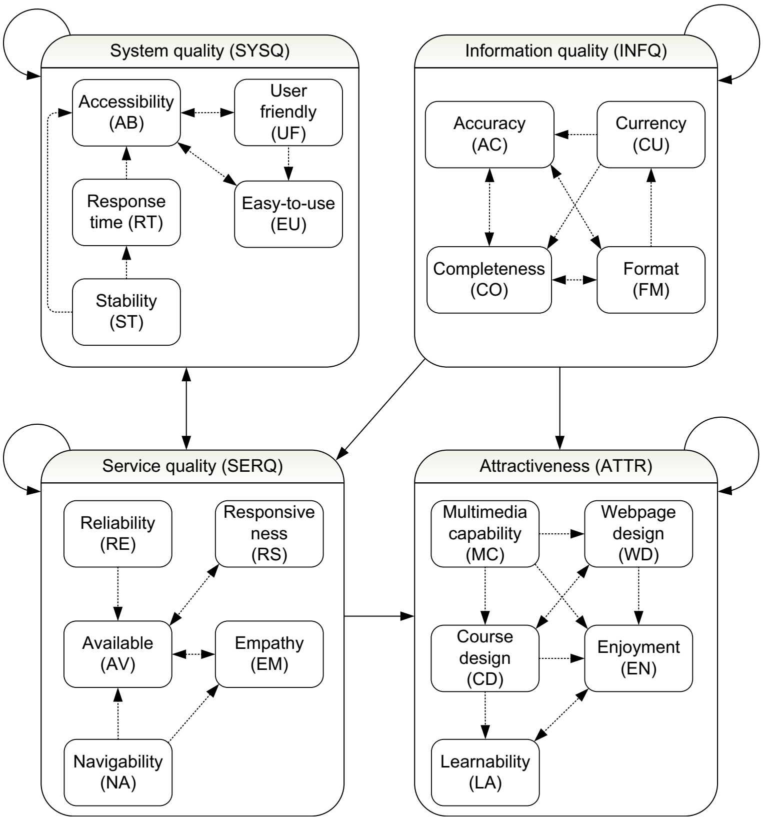


Fig. 3 Quality attribute network model of e-learning systems

The solid arrows between quality clusters signify that the sub-attribute within the cluster is affected by a sub-attribute within other clusters. For example, the Stability in *System quality* cluster is affected by the *Reliability* in the *Service quality* cluster and also affects Reliability. As such, the *System quality* cluster and the *Service quality* cluster are connected with a bidirectional solid arrow. Detailed correlations between sub-attributes in each quality cluster are shown in Appendix 5.

The unweighted supermatrix is constructed according to the network built in Fig. 3. The supermatrix structure is shown following Eq. 3, and the detailed version of the supermatrix is provided in Appendix 1.

$$W_B = \begin{array}{c} \\ \text{SYSQ} \\ \text{INFQ} \\ \text{SERQ} \\ \text{ATTR} \end{array} \begin{array}{c} \begin{array}{cccc} \text{SYSQ} & \text{INFQ} & \text{SERQ} & \text{ATTR} \end{array} \\ \begin{bmatrix} W_{11} & 0 & W_{13} & 0 \\ 0 & W_{22} & 0 & 0 \\ W_{31} & W_{32} & W_{33} & 0 \\ 0 & W_{42} & W_{43} & W_{44} \end{bmatrix} \end{array} \quad (3)$$

The 1 to 9 scale developed by Saaty is used, and paired comparisons are made to build up the supermatrix. Also in this step, the consistency of each comparison is checked (see C.I. in Table 5). In each column of a supermatrix, there is either a normalized eigenvector or all of its block entries are zero.

For example, the first column of the matrix W_{11} in the supermatrix (Appendix 1) displays the eigenvector values calculated from the pairwise comparison matrix (Table 4). To construct Table 4, each of the 5 sub-attributes of the *System quality* (SYSQ) cluster were compared, and the relative importance of each, in terms of *Accessibility* (AB), was determined. The highest eigenvector value (0.4904) of *Easy-to-use* (EU) means that the *Easy-to-use* sub-attribute has the strongest influence on the *Accessibility* sub-attribute among the 5 sub-attributes within the *System quality* cluster.

In this step, the supermatrix is unweighted. Because each column consists of several eigenvectors, each of which sums to one (in a column of a stochastic), the entire column of the matrix may sum to an integer greater than one. The supermatrix must be stochastic to derive meaningful limiting priorities. For this reason, to achieve the weighted supermatrix, the influences of the clusters on each cluster with respect to the control criterion are determined, which yields an eigenvector of influence of the clusters on each cluster. Table 5 shows the priority weights of the clusters.

Next, the unweighted supermatrix is multiplied by the priority weights from the clusters, which yields the weighted supermatrix in Appendix 2.

Finally, the supermatrix is in steady state by multiplying the weighted supermatrix by itself until its row values converge to the same value for each column, as shown in Appendix 3. The following three-step procedure proposed by Saaty [34] is used to approximate priorities.

Step 1. *Step 1*. Sum the values in each column of the pairwise comparison matrix.

Step 2. *Step 2*. Divide each element in the column by the sum of its respective column. The resultant matrix is referred to as the normalized pairwise comparison matrix.

Step 3. *Step 3*. Sum the elements in each row of the normalized pairwise comparison matrix, and divide the sum by the *n* elements in the row. These final numbers provide an estimate of the relative priorities for the elements being compared with respect to the upper level criterion. Priority vectors must be derived for all comparison matrices.

As a result of this process, we can see the numerical value of the degree of influence of each quality cluster and sub-attribute on the overall learning system. The result of the final priority weight calculation is summarized in Table 6.

Table 6 shows that Format, Stability, Completeness and Accuracy have the largest effects on the overall quality of the learning system and that the Information quality cluster decides more than 40% of the overall quality. Because the Information quality cluster represents the level and the fidelity of the learning contents, the highest weight of this quality cluster reflects the characteristics of learning systems. Additionally, the fact that the weight of Stability is high shows that in a e-learning system, a stable connection to the internet is an important quality characteristic.

In the next section, we evaluate and compare three different types of e-learning systems used by Kyunghee Cyber University based on the priority weights of each quality attribute.

Table 4 Pairwise comparison matrix and eigenvector for Accessibility (AB)

AB	AB	RT	ST	UF	EU	Eigenvector
AB	1	1/3	1/2	1/4	1/6	0.0558
RT	3	1	2	1/2	1/4	0.1407
ST	2	1/2	1	1/3	1/5	0.0867
UF	4	2	3	1	1/3	0.2264
EU	6	4	5	3	1	0.4904

Table 5 Weight matrix of the main quality clusters

	SYSQ	INFQ	SERQ	ATTR
SYSQ	0.7500	0.0000	0.6250	0.0000
INFQ	0.0000	1.0000	0.1365	0.6144
SERQ	0.2500	0.0000	0.2385	0.1172
ATTR	0.0000	0.0000	0.0000	0.2684
C.I.*	0.0000	0.0000	0.0091	0.0368

*C.I.: Consistency Index

5 Evaluation of e-learning systems

Kyunghee Cyber University, an online university, manages distance learning degree programs for adult learners at the bachelor level across 29 majors for approximately 13,000 students. The university conducts lectures using remote methods of education through information and telecommunication technology, multimedia technology, and related software. In addition to their coursework, over 70% of the students are also employed in fields like consulting and IT development.

5.1 Sample e-learning systems for evaluation

The web-based methods of education employed at Kyunghee Cyber University can be divided into three categories: VoD (video-on-demand)-based learning, On-screen-based learning and Animation-based learning. We attempted to evaluate all three types of learning systems using the one evaluation method that we have proposed. Brief explanations of each system are as follows:

- *VoD-based learning*: The learning materials are video files of an instructor's lectures. Students study with the video files and text notes on a computer screen. VoD-based learning is a typical and common method of on-line education.
- *On-screen-based learning*: The learning materials are files that record video directly from an instructor's computer screen while he or she performs a lecture. This method is used primarily in computer software classes such as MS-office and Photoshop, and students study easily by following the instructor's explanations and lecture screen.
- *Animation-based learning*: The learning materials are made with animation tools, such as Flash. The instructor is represented by an animation character on a screen, and the character performs the lecture on the screen. In this method, various colorful animations are usually used.

Fig. 4 shows a sample screen of a VoD-based learning system.

To demonstrate the learning system quality evaluation process using the proposed method in this study, we evaluated all three of these types of learning systems.

Table 6 Final weights of clusters and sub-attributes

Category	System quality (0.3619)					Information quality (0.4081)				
Sub-attributes	AB	RT	ST	UF	EU	AC	CO	CU	FM	
Weight	0.0892	0.0364	0.1182	0.0579	0.0602	0.1103	0.1151	0.0556	0.1271	
Category	Service quality (0.1594)					Attractiveness (0.0706)				
Sub-attributes	RE	AV	NA	RS	EM	MC	CD	LA	WD	EN
Weight	0.0308	0.0415	0.0392	0.0195	0.0284	0.0275	0.0212	0.0036	0.0132	0.0051

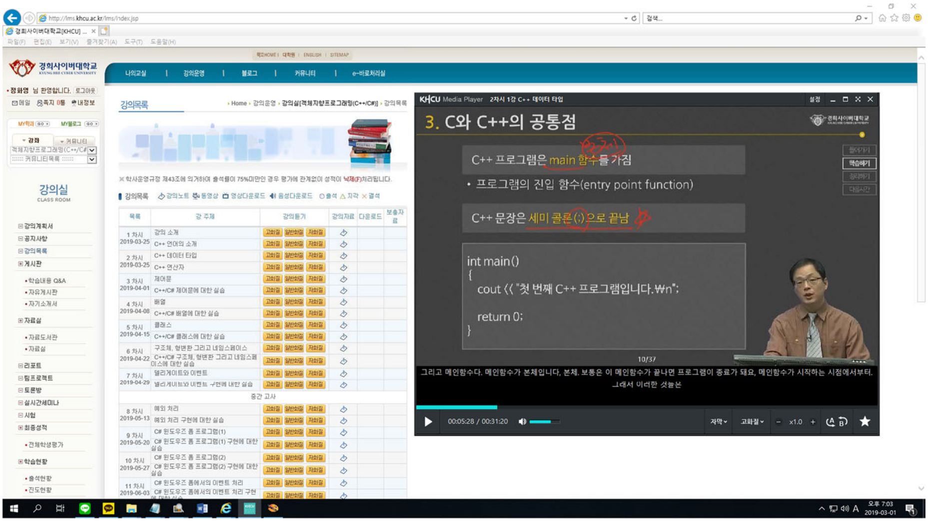


Fig. 4 The sample screen of a lecture from Kyunghee Cyber University

5.2 Evaluation process and results

The evaluation process yielded a total of 150 complete, valid questionnaires. All of the respondents were undergraduate students of Kyunghee Cyber University and had experience using all three types of e-learning systems. We chose 150 participants who had sufficient experience using the three types of learning systems and who understood the evaluation process and its objective. They had used each learning system more than 50 times by the time they filled out the questionnaires for learning system quality evaluation. The gender breakdown was 44% female and 56% male, and 95% were third year students.

In the questionnaire, students were asked to express their agreement with a series of statements based on a five-point Likert-type scale, with anchors ranging from "strongly agree" to "strongly disagree". Because the evaluators were not experts in software quality evaluation, we used questionnaires made up of linguistic values.

To calculate the overall quality with the priority weight of quality attributes and the evaluation scores of users, the linguistic variables in the questionnaires were converted to the numerical scale values shown in Table 7. The full questionnaires can be found in Appendix 4.

Table 8 shows the evaluation results. The *scale value* represents the average of the converted evaluation scores from the questionnaires shown in Appendix 6. The *weighted value* is the final evaluation score that came from multiplying the *scale value* by the priority weight of each quality attribute in Table 6 as in Eq. (4) below.

Table 7 Measurement scales for qualitative values

Linguistic variable	Scale value
Strongly agree	1.00
Agree	0.80
Average	0.60
Disagree	0.40
Strongly disagree	0.20

Table 8 Evaluation results of e-learning system samples

Attributes	VoD		On-screen		Animation	
	Scale value	Weighted score	Scale value	Weighted score	Scale value	Weighted score
System quality						
Accessibility	0.92	0.0821	0.88	0.0785	0.90	0.0803
Response time	0.88	0.0320	0.86	0.0313	0.88	0.0320
Stability	0.90	0.1064	0.88	0.1040	0.88	0.1040
User friendly	0.84	0.0486	0.82	0.0475	0.86	0.0498
Easy-to-use	0.90	0.0542	0.82	0.0494	0.84	0.0506
Information quality						
Accuracy	0.82	0.0904	0.90	0.0993	0.90	0.0993
Completeness	0.88	0.1013	0.90	0.1036	0.92	0.1059
Currency	0.54	0.0300	0.82	0.0456	0.64	0.0356
Format	0.82	0.1042	0.80	0.1017	0.84	0.1068
Service quality						
Reliability	0.88	0.0271	0.86	0.0265	0.84	0.0259
Availability	0.92	0.0382	0.88	0.0365	0.90	0.0374
Navigability	0.94	0.0368	0.88	0.0345	0.90	0.0353
Responsiveness	0.92	0.0179	0.88	0.0172	0.90	0.0176
Empathy	0.90	0.0256	0.88	0.0261	0.94	0.0267
Attractiveness						
Multimedia capability	0.88	0.0242	0.88	0.0242	0.86	0.0237
Course design	0.88	0.0187	0.86	0.0182	0.86	0.0182
Learnability	0.88	0.0032	0.82	0.0030	0.84	0.0030
Webpage design	0.80	0.0106	0.78	0.0103	0.80	0.0106
Enjoyment	0.82	0.0042	0.78	0.0040	0.78	0.0040
Sum	16.32	0.8557	16.22	0.8612	16.28	0.8664
Ranking	1	3	3	2	2	1

$$Weighted\quad score = Scale\quad value \times Weight\quad of\ sub\!-\!attribute \tag{4}$$

The *total quality* score comes from the sum of scores of each sub-attribute. That is, the *scale value* equates to a score which does not account for the priority weights of each attribute, and the *weighted score* is a score that reflects the weights.

Without considering the weights of the quality attributes, the evaluation value of the VoD-based learning system (16.32) was the highest quality value, but if the weights are considered, the Animation-based learning system showed the highest quality value (0.8664). This discrepancy results from the relatively low performance of the VoD-based learning system in the Information quality cluster, which is more heavily weighted than the other clusters. In reality, because the video files for the VoD-based learning system are renewed every three years, their Accuracy, Completeness, and Currency values are relatively low.

Through our method, we can evaluate and compare different kinds of learning systems with concrete figures, as demonstrated in Table 8, and determine which factors are more important than others when constructing a e-learning system.

6 Conclusions and discussions

Many studies have been performed to identify the factors influencing and deciding the quality of e-learning systems, but there are few studies that consider the relative weights of each factor and the correlations between them. In this paper, a quality evaluation method is developed that accounts for the correlations between quality clusters and their sub-attributes. The resulting quality evaluation model consists of 4 main quality clusters and 19 sub-attributes, and a network model reflecting the correlations is constructed. Based on this network, the priority weights of each of the attributes are calculated using the ANP. The analysis shows that the Information quality cluster, which represents learning content, subjects and items, is the most important factor in an e-learning system and that System quality is second. These results indicate that providing substantial learning content and stable system functions must take precedence over visual attractiveness or website design in developing learning systems and therefore suggest guidelines for constructors and instructors to follow to improve their learning systems.

In addition, we applied these weights to evaluate the three types of e-learning systems employed by Kyunghee Cyber University. The empirical evaluation results show that, because the rankings of quality evaluations change depending upon whether the weights are considered, applying the weights is important to achieve a more thorough evaluation. Moreover, with the proposed evaluation model, we can compare different kinds of learning systems with concrete numbers under the same evaluation criteria.

It is necessary to evaluate various kinds of software systems using the same quality standard, and ISO/IEC 9126 is one such suggested quality evaluation standard. However, there are limitations in applying the standard to various kinds of software, and Jung at. el. [20] noted that the quality attribute group in ISO/IEC 9126 has exhibited such limitations when actually applied. Additionally, Villalba et al. [39] showed that the standard is generic and therefore not directly applicable to the specific domain of evaluation. As such, an effort is required to fit it to each evaluation subject and object.

In this paper, we extracted the quality attributes related to the evaluation of e-learning systems and divided them into 4 groups. However, to standardize the attribute groups applied in this paper, an in-depth review by a formal organization may be required.

To evaluate quality with this process, experts must first construct a quality attribute network and perform the ANP through pairwise comparisons between attributes. While this step may initially seem like a hardship, there is a direct correlation between the accuracy of the results and the effort exerted in constructing the quality evaluation model.

The quality attribute matrix suggested in this paper is not a universal standard that can be applied to various kinds of learning systems or software. As we have mentioned, the quality attribute matrix and its correlations and weights should be changed according to the evaluation object and goal. The quality matrix and the correlations and weights suggested in this paper focus on the evaluation and comparison of three different types of e-learning platforms. As such, there are limitations in terms of being able to apply this matrix to different systems. Although it is very difficult to construct one quality attribute matrix that can be applied to various software without modifications. We will continue trying to improve the proposed method so that it can be applied to a larger variety of systems.

Appendix 1. Un-weighted supermatrix

		SYSQ					INFQ				SERQ					ATTR				
		AB	RT	ST	UF	EU	AC	CO	CU	FM	RE	AV	NA	RS	EM	MC	CD	LA	WD	EN
S	AB	0.0558	0.0000	0.0000	0.9677	0.2969	0.0000	0.0000	0.0000	0.0000	0.1673	0.4745	0.2518	0.1473	0.0852	0.0000	0.0000	0.0000	0.0000	0.0000
Y	RT	0.1407	0.0323	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1150	0.0407	0.1259	0.5628	0.0558	0.0000	0.0000	0.0000	0.0000	0.0000
S	ST	0.0867	0.9677	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5277	0.2592	0.1479	0.1238	0.0683	0.0000	0.0000	0.0000	0.0000	0.0000
Q	UF	0.2264	0.0000	0.0000	0.0323	0.5396	0.0000	0.0000	0.0000	0.0000	0.0950	0.0770	0.2518	0.0905	0.2865	0.0000	0.0000	0.0000	0.0000	0.0000
	EU	0.4904	0.0000	0.0000	0.0000	0.1635	0.0000	0.0000	0.0000	0.0000	0.0950	0.1486	0.2226	0.0756	0.5042	0.0000	0.0000	0.0000	0.0000	0.0000
I	AC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0793	0.5416	0.0000	0.2385	0.1793	0.2833	0.2699	0.1584	0.2869	0.1716	0.5538	0.5637	0.2879	0.1750
N	CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.5008	0.0772	0.0000	0.6250	0.5727	0.5048	0.5476	0.1258	0.0829	0.2426	0.2420	0.2576	0.2046	0.2462
F	CU	0.0000	0.0000	0.0000	0.0000	0.0000	0.1400	0.1344	0.0323	0.0000	0.1410	0.1494	0.0559	0.6147	0.5553	0.2426	0.0719	0.1095	0.1692	0.2894
Q	FM	0.0000	0.0000	0.0000	0.0000	0.0000	0.2799	0.2468	0.9677	0.1365	0.1070	0.0625	0.1266	0.1011	0.0749	0.3432	0.1323	0.0692	0.3383	0.2894
S	RE	0.1649	0.1678	0.4645	0.1250	0.1429	0.0000	0.0000	0.0000	0.0000	1.0000	0.0867	0.0000	0.0000	0.0000	0.2222	0.1044	0.0514	0.0780	0.0525
E	AV	0.5058	0.1367	0.1895	0.2500	0.1429	0.0000	0.0000	0.0000	0.0000	0.0000	0.0558	0.0000	0.9677	0.6250	0.2559	0.1234	0.0646	0.1521	0.1678
R	NA	0.1001	0.0725	0.0871	0.2500	0.2857	0.0000	0.0000	0.0000	0.0000	0.0000	0.2264	1.0000	0.0000	0.2385	0.1717	0.5664	0.4970	0.1609	0.2758
Q	RS	0.1556	0.5078	0.1534	0.1250	0.1429	0.0000	0.0000	0.0000	0.0000	0.0000	0.1407	0.0000	0.0323	0.0000	0.1280	0.0768	0.1410	0.0805	0.0619
	EM	0.0726	0.1152	0.1055	0.2500	0.2856	0.0000	0.0000	0.0000	0.0000	0.0000	0.4904	0.0000	0.0000	0.1365	0.2222	0.1290	0.2460	0.5285	0.4420
A	MC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.2969	0.0000	0.2385	0.4146
T	CD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1634	0.5396	0.6250	0.1748
T	LA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1634	0.0000	0.0899
R	WD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5397	0.0000	0.1365	0.2598
	EN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2670	0.0000	0.0609

Appendix 2. Weighted supermatrix

		SYSQ					INFQ				SERQ					ATTR				
		AB	RT	ST	UF	EU	AC	CO	CU	FM	RE	AV	NA	RS	EM	MC	CD	LA	WD	EN
S	AB	0.0419	0.0000	0.0000	0.7258	0.2227	0.0000	0.0000	0.0000	0.0000	0.1046	0.2966	0.1574	0.0921	0.0533	0.0000	0.0000	0.0000	0.0000	0.0000
Y	RT	0.1055	0.0242	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0719	0.0254	0.0787	0.3518	0.0349	0.0000	0.0000	0.0000	0.0000	0.0000
S	ST	0.0650	0.7258	0.7500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3298	0.1620	0.0924	0.0774	0.0427	0.0000	0.0000	0.0000	0.0000	0.0000
Q	UF	0.1698	0.0000	0.0000	0.0242	0.4047	0.0000	0.0000	0.0000	0.0000	0.0594	0.0481	0.1574	0.0566	0.1791	0.0000	0.0000	0.0000	0.0000	0.0000
	EU	0.3678	0.0000	0.0000	0.0000	0.1226	0.0000	0.0000	0.0000	0.0000	0.0594	0.0929	0.1391	0.0473	0.3151	0.0000	0.0000	0.0000	0.0000	0.0000
I	AC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0793	0.5416	0.0000	0.2385	0.0245	0.0387	0.0368	0.0216	0.0392	0.1054	0.3403	0.3463	0.1769	0.1075
N	CO	0.0000	0.0000	0.0000	0.0000	0.0000	0.5008	0.0772	0.0000	0.6250	0.0782	0.0689	0.0747	0.0172	0.0113	0.1491	0.1487	0.1583	0.1257	0.1513
F	CU	0.0000	0.0000	0.0000	0.0000	0.0000	0.1400	0.1344	0.0323	0.0000	0.0192	0.0204	0.0076	0.0839	0.0758	0.1491	0.0442	0.0673	0.1040	0.1778
Q	FM	0.0000	0.0000	0.0000	0.0000	0.0000	0.2799	0.2468	0.9677	0.1365	0.0146	0.0085	0.0173	0.0138	0.0102	0.2109	0.0813	0.0425	0.2079	0.1778
S	RE	0.0412	0.0420	0.1161	0.0313	0.0357	0.0000	0.0000	0.0000	0.0000	0.2385	0.0207	0.0000	0.0000	0.0000	0.0260	0.0122	0.0060	0.0091	0.0062
E	AV	0.1265	0.0342	0.0474	0.0625	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000	0.0133	0.0000	0.2308	0.1491	0.0300	0.0145	0.0076	0.0178	0.0197
R	NA	0.0250	0.0181	0.0218	0.0625	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0540	0.2385	0.0000	0.0569	0.0201	0.0664	0.0582	0.0189	0.0323
Q	RS	0.0392	0.1270	0.0384	0.0313	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000	0.0336	0.0000	0.0077	0.0000	0.0150	0.0090	0.0165	0.0094	0.0073
	EM	0.0182	0.0288	0.0264	0.0625	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000	0.1170	0.0000	0.0000	0.0326	0.0260	0.0151	0.0288	0.0619	0.0518
A	MC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2684	0.0797	0.0000	0.0640	0.1113
T	CD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0439	0.1448	0.1678	0.0469
T	LA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0439	0.0000	0.0241
R	WD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1449	0.0000	0.0366	0.0697
	EN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0797	0.0000	0.0163

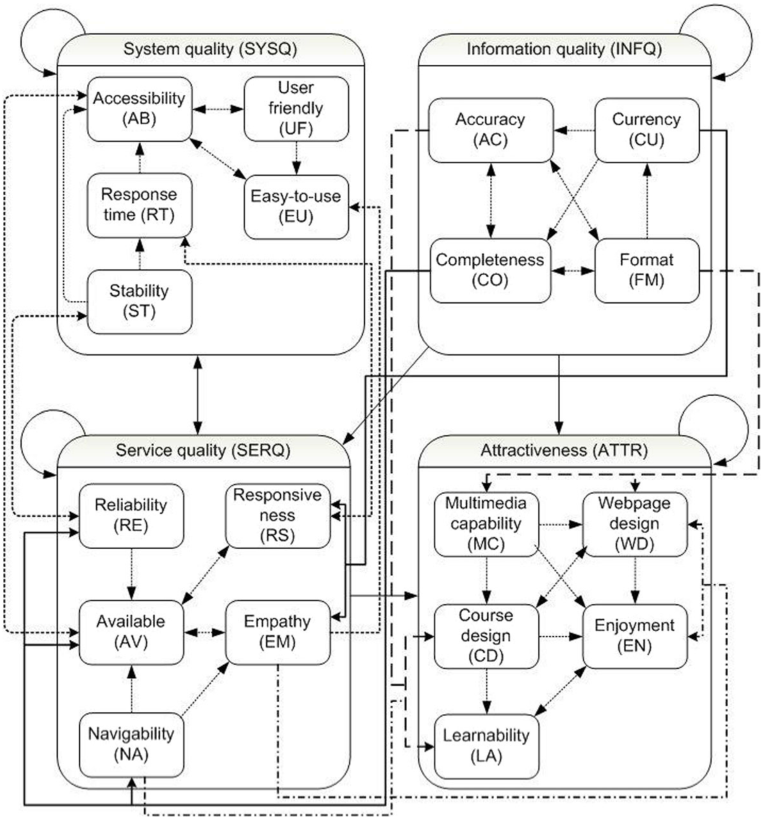
Appendix 3. Limited supermatrix (Normalized)

		SYSQ					INFQ				SERQ					ATTR				
		AB	RT	ST	UF	EU	AC	CO	CU	FM	RE	AV	NA	RS	EM	MC	CD	LA	WD	EN
S	AB	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892
Y	RT	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364	0.0364
S	ST	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182	0.1182
Q	UF	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579	0.0579
	EU	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602	0.0602
I	AC	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103
N	CO	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151	0.1151
F	CU	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
Q	FM	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271	0.1271
S	RE	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308
E	AV	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415
R	NA	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392
Q	RS	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195
	EM	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284	0.0284
A	MC	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275
T	CD	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212	0.0212
T	LA	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036
R	WD	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132	0.0132
	EN	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051

Appendix 4. Questionnaires for evaluating web-based learning systems (WBLS)

Criteria	Question/Statement	Reference
SYSQ	AB. I can easily access the WBLS anytime I want to use it.	Pituch and Lee [29]
	RT. The waiting time for loading learning materials is reasonable.	H.F. Lin [25]
	EU. It is easy for me to understand how to study using the WBLS.	Davis et al. [12]
	ST. The WBLS is consistently stable while I study without system errors.	
	UF. The supporting tools, processes and communications provided by the WBLS are friendly to use.	
INFQ	AC. The WBLS can provide me with accurate and precise information to do my study.	Rai et al. [30]
	CU. Learning materials from the WBLS are always up to date.	
	CO. The WBLS provides me with a complete set of learning materials without construction errors in the learning content.	H.F. Lin [25]
	FM. The content of learning materials (such as range, depth and structure) are clearly presented on the web-page.	
SERQ	RE. The WBLS provides the right solution to my requests.	H.F. Lin [25]
	RS. I can receive a quick response from the WBLS when I encounter technical problems or require communication.	
	AV. The WBLS is present and ready for my immediate use at any time.	
	NA. The WBLS has easy navigation for finding learning materials.	H.F. Lin [25]
	EM. According to the learner's background, the WBLS provides individual attention to the learner.	H.F. Lin [25]
ATTR	MC. The WBLS fully uses multimedia features to increase learning efficiency.	
	WD. The webpage design of the WBLS is well-organized.	H.F. Lin [25]
	CD. The WBLS provides appropriate learning scenarios to facilitate communications.	
	EN. Using the WBLS provides learners with enjoyment.	
	LA. Using the WBLS is helpful for attaining a maximal level of learning performance.	

Appendix 5. Correlations between sub-attributes in each quality cluster



Appendix 6. Statistical analysis for score values of users

Attribute	VoD				On-screen				Animation			
	Min.	Max.	Avg.	Std.	Min.	Max.	Avg.	Std.	Min.	Max.	Avg.	Std.
System quality												
Accessibility	0.80	1.00	0.92	0.0982	0.80	1.00	0.88	0.0985	0.80	1.00	0.90	0.1006
Response time	0.80	1.00	0.88	0.0977	0.80	1.00	0.86	0.0922	0.80	1.00	0.88	0.0985
Stability	0.80	1.00	0.90	0.0994	0.80	1.00	0.88	0.0931	0.80	1.00	0.88	0.0990
User friendly	0.80	1.00	0.84	0.0804	0.80	1.00	0.82	0.0603	0.80	1.00	0.86	0.0922
Easy-to-use	0.80	1.00	0.90	0.1006	0.80	1.00	0.82	0.0632	0.80	1.00	0.84	0.0804
Information quality												
Accuracy	0.60	1.00	0.82	0.1083	0.80	1.00	0.90	0.1006	0.80	1.00	0.90	0.1006
Completeness	0.80	1.00	0.88	0.0985	0.80	1.00	0.90	0.1005	0.80	1.00	0.92	0.0980
Currency	0.40	0.60	0.54	0.0922	0.60	1.00	0.82	0.1671	0.60	0.80	0.64	0.0804
Format	0.80	1.00	0.82	0.0603	0.60	1.00	0.80	0.1272	0.80	1.00	0.84	0.0821
Service quality												
Reliability	0.80	1.00	0.88	0.0985	0.80	1.00	0.86	0.0922	0.80	1.00	0.84	0.0836
Availability	0.80	1.00	0.92	0.0990	0.80	1.00	0.88	0.0985	0.80	1.00	0.90	0.1006
Navigability	0.80	1.00	0.94	0.0922	0.80	1.00	0.88	0.0990	0.80	1.00	0.90	0.1005
Responsiveness	0.80	1.00	0.92	0.0990	0.80	1.00	0.88	0.0993	0.60	1.00	0.90	0.1046

Attribute	VoD				On-screen				Animation			
	Min.	Max.	Avg.	Std.	Min.	Max.	Avg.	Std.	Min.	Max.	Avg.	Std.
Empathy	0.80	1.00	0.90	0.1005	0.60	1.00	0.88	0.1334	0.80	1.00	0.94	0.0922
Attractiveness												
Multimedia	0.80	1.00	0.88	0.0980	0.80	1.00	0.88	0.0980	0.60	1.00	0.86	0.0945
capability	0.80	1.00	0.88	0.0993	0.60	1.00	0.86	0.1288	0.60	1.00	0.86	0.0960
Course design	0.80	1.00	0.88	0.0975	0.60	1.00	0.82	0.1083	0.60	1.00	0.84	0.1003
Learnability	0.60	1.00	0.80	0.0899	0.60	1.00	0.78	0.1099	0.60	1.00	0.80	0.1272
Webpage design	0.60	1.00	0.82	0.1408	0.60	1.00	0.78	0.1124	0.60	1.00	0.78	0.1083
Enjoyment												

(*Number of respondents = 150*)

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