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Ranking the Criteria Effective in the Selection of E-Learning System by Fuzzy AHP (F-AHP) Method

E-Öğrenme Sistemi Seçiminde Etkili Kriterlerin Bulanık AHP (F-AHP) Yöntemiyle Sıralanması

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ABSTRACT: E-learning systems are one of the effective methods used for education. It is obvious that both during the Pandemic period when distance education is actively used and in normal life, participants apply to e-learning systems to follow lessons or improve themselves. Computer and internet applications are getting into education more and more day by day. Education through e-learning, which can work online or offline, is more and more effective every day. Thanks to these systems, education becomes more transparent, accessible and fairly distributed. Since many criteria will have an impact on the selection of a suitable e-learning system, these criteria were determined in the study and presented to expert opinions. In the selection of e-learning systems, 10 criteria were selected by literature review and the criteria were conveyed to the experts. The criteria were listed using the fuzzy AHP method. The most effective criterion in the study was found to be interaction. This criterion is followed by ease of use, content and reliability criteria.

Keywords: e-learning, distance learning, mobile learning, AHP, F-AHP, MCDM.

ÖZ: E-öğrenme sistemleri eğitimde kullanılan etkili yöntemlerden biridir. Hem uzaktan eğitimin aktif olarak kullanıldığı Pandemi döneminde hem de normal yaşamda katılımcıların dersleri takip etmek veya kendilerini geliştirmek için e-öğrenme sistemlerine başvurdukları açıktır. Bilgisayar ve internet uygulamaları her geçen gün daha fazla eğitimin içine girmektedir. Çevrimiçi veya çevrimdışı çalışabilen e-öğrenme yoluyla eğitim, her geçen gün daha da etkilidir. Bu sistemler sayesinde eğitim daha şeffaf, erişilebilir ve adil bir şekilde dağıtılmaktadır. Uygun bir e-öğrenme sisteminin seçiminde birçok kriterin etkisi olacağından, çalışmada bu kriterler belirlenmiş ve uzman görüşlerine sunulmuştur. E-öğrenme sistemlerinin seçiminde literatür taraması yapılarak 10 kriter seçilmiş ve kriterler uzmanlara aktarılmıştır. Bulanık AHP yöntemi kullanılarak kriterler listelenmiştir. Araştırmada en etkili ölçüt etkileşim olarak bulunmuştur. Bu kriteri kullanım kolaylığı, içerik ve güvenilirlik kriterleri takip etmektedir.

Anahtar kelimeler: e-öğrenme, mesafeli öğrenme, mobil öğrenme, AHP, F-AHP, MCDM.

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Electronic learning (E-learning) systems are systems that educate students. In these systems, students are provided to learn the necessary information by using tools such as virtual classrooms. These systems are also network-supported platforms that can work online or offline and can be personalised according to the user's wishes. And the systems usually have a specific interface that allows the user to ask questions to the instructor. E-learning systems have features other than those listed, which are effective in selecting the e-learning system. E-learning was defined as the use of digital technology for education (Tudor et al., 2018). In the literature, it is seen that the concept of e-learning is used in ways such as web-based learning, online learning, mobile learning, and virtual or digital collaboration learning (Adedoyin & Soykan, 2020; Azlan et al., 2020; Mahalakshmi & Radha, 2020; Männistö et al., 2020; Wirani & Manurung; 2020). The prevalence of e-learning systems depends on the quality of knowledge transfer and the development and improvement in the effectiveness of the platform (Khan et al., 2019). E-learning systems are easy to access, less costly, provide the opportunity to access educational content at any place and time, reach more students at the same time, do not need a classroom, are repeatable, and can be slowed down and accelerated. It has advantages such as providing equal education opportunities for everyone and updating the curriculum anytime.

It is undeniable that education is a very important requirement for people around the world and should be accessible to everyone. The delivery of this training to people and its effective and efficient implementation is an important element in illuminating the future. The COVID-19 pandemic has also revealed the necessity of taking new and up-to-date steps in education. According to the World Economic Forum, COVID-19 has caused schools to close around the world and left more than 1.2 billion children out of face-to-face education. As a result, teaching has moved to distance and digital platforms, and there has been a significant increase in the use of e-learning systems. The systems were also used in the pre-epidemic period, but their importance was even better understood during and after the epidemic.

According to Global News Wire (2020), mobile learning has been the fastest-growing market in the industry, with an average annual growth rate of 20%. The same report also expects the global mobile learning market to reach US$ 80.1 billion by 2027. According to Reuters' report, the global e-learning market will reach a value of 398.15 billion dollars in 2026. The latest report from the National Center for Education Statistics (NCES, 2019) shows that the number of enrollments in distance education courses has increased. However, the overall university enrollment rate has decreased (NCES, 2019). According to the e-Learning Market Intelligence Report, the Global eLearning Market is projected to reach USD 352,348.96 million by 2027 from USD 126,199.67 million in 2021, at a compound annual growth rate (CAGR) of 18.66% during the forecast period. According to the Comprehensive Learning Management System (LMS) Market Report and Trends (2021), the Global e-learning market is expected to reach a size of 374 billion USD by 2026. The market is expected to grow at a compound annual growth rate of 14.6. According to the same report, the most important reason for this rapid growth is the Covid-19 quarantine and the accompanying global closures.

The general aim of societies is to strengthen the development of people's intellectual capital to raise self-sufficient, responsible individuals who can understand

and explain. The more these goals can be achieved, the longer they will be able to survive in societies. The quality of a country's human intellectual capital should include developing skills such as questioning, exploring, inventing, reflecting interest, and communicative and collaborative skills among students (Malik et al., 2021). In this way, societies can improve their technology and knowledge levels. The investment in education and the effort spent in development will ensure that nations are always one step ahead. Having a successful e-learning system can affect the educational institution's image and save institution resources (funds, time, and labor) (Taha, 2014).

Students currently in various levels of education can be defined as members of the digital native or network generation born in the digital age and interacting with digital technology from childhood (Chelvarayan et al., 2020). These individuals can use mobile devices and the socialization and education platforms they provide. If this way of learning is adopted by students more, the quality of education and the number of individuals who can access education will increase. Due to the growing popularity of e-learning platforms and the rapid increase in the number of learning systems available, choosing the right platform for students has become crucial.

The aim of the study is to determine the factors that are effective in the selection of e-learning systems, to show the designers and trainers which criteria are more important, and to focus on these issues. During the design phase of the study, criteria were determined by literature review, the criteria used in other studies, and the methods used were presented. The use of a large number of criteria as e-learning system evaluation criteria and the addition of up-to-date criteria makes this study different from other studies.

The study was conducted taking the opinions of 16 experts (software engineers, computer engineers, computer teachers, academicians, etc.) on the criteria and processing them with the Fuzzy Analytic Hierarchy Process (F-AHP), which is a Multi-Criteria Decision-Making Method (MCDM). The criteria determined by a wide literature review were presented to the experts, and they were asked to compare these criteria in pairs. Since simultaneous control was also performed while making paired comparisons, no problems were encountered in the consistency ratios, and consistency values below 0.10 were obtained.

Selection of E-Learning Systems, Methods, and Criteria

It has been observed that different criteria are considered in studies on e-learning systems. The criteria used in the scanned studies are given in Table 1. Using cross-case analysis, Soong et al. (2001) examined the websites according to the criteria they determined. Covella and Olsina Santos (2002) conducted a case study to identify, evaluate, and compare the quality of four typical sites and applications with e-learning functionality. Pruengkarn et al. (2005) used the main criteria and their sub-criteria for selection with the SWING method in their study. The study has six main criteria and a total of 21 sub-criteria.

Shee and Wang (2008) evaluated web-based e-learning systems using the AHP method and determined criteria. Four main criteria: user interface, features of the learning community, system content, and customization. These main criteria have 13 sub-criteria. For the interface criterion, the sub-dimensions of ease of use, user-friendliness, ease of understanding, operational stability; for the characteristics of the

learning community criterion, the sub-dimensions of ease of communication with other students and educators, ease of access to shared data, ease of sharing learning materials; for the system content criterion, the sub-dimension of useful and sufficient content; and finally for the personalisation criterion, the sub-dimensions of checking and saving progress were examined. In the study, the most important criterion for users was found to be the interface. Content, learning community, and personalization follow this criterion in order.

Table 1

E-Learning Systems Selection Criteria

Year	Author/s	Criteria
2001	Soong et al.	Instructors And Students Technical Competency, Human Factors, Mind-Set (About Learning), Collaboration, Perceived IT İnfrastructure, Technical Support
2002	Covella and Olsina Santos	Course/Course Features, Student Features, Learning Environment Features, Usability, Confidentiality, Reliability, Efficiency, Certificate Information, Virtual Community
2005	Pruengkarn et al.	Functionality, Reliability, Usability, Efficiency, Sustainability, Portability
2008	Shee and Wang	User Interface, Features of Learning Community, System Content, Personalization
2009	Chao and Chen	E-Learning Material, Learning Record, Self-Learning, Synchronous Learning, Quality of Web Learning Platform
2012	Syamsuddin	Functionality, Reliability, Usability, Efficiency, Sustainability, Portability
2012	Alias et al.	Ease Of Use, Appearance, Linkage, Structure and Layout, Information, Reliability, Efficiency, Support, Communication, Security.
2016	Jain et al.	Accurate/Comprehensible Content, Current/Full Content, Personalization, Security and Navigation, Interactions, User Interface
2017	Garg	Right And Understandable Content, Complete Content, Personalization, Security, Navigation, Interactivity, User Interface
2018	Anggrainingsih et al.	University Policies (Financial Policy), University Regulation (Regulation Policy), Technical Support, Seminars and Training Availability, Portability Products, Reliability Product, Ease to Understand and Ease to Use, Design and User Interface System, Course Quality, Relevant Content, Completeness of Content, Flexibility to Taking Course, Expertise to Use a Computer, Expertise to Use the Internet, Attitudes Toward E-Learning, Forum / Discussion Availability, Attitudes Toward Student, Respond Time, Liveliness Lectures, Attitudes Toward E-Learning
2018	Garg et al.	Functionality, Sustainability, Usability, Portability, Reliability, Efficiency, Ease of Learning, System Content, General Factors
2018	Mohammed et al.	Human resources, Specific ICT Infrastructure for E-Learning, Basic ICT Infrastructure for E-Learning, Strategic Readiness for E-Learning Implementation, Legal and Formal Readiness for E-Learning Implementation
2018	Alhabeeb and Rowley	Student Features, E-Learning System, Experience, Ease of Access, Instructor Features, E-Learning Support Ease of Use, Support and Training, E-Learning Tools, Participation
2019	Khan et al.	Functionality, Sustainability, Portability, Reliability, Usability, Efficiency, Learning Community, Personalization, System Content, General Factors

2019	Fitriastuti et al.	Reliability, Flexibility, Integration, Accessibility, Response Time, Completeness, Accuracy, Format, Service Reliability, Service Support, User's Empathy
2020	Chelvarayan et al.	Performance Expectancy, Effort Expectancy, Social Influence, Quality of Service, Perceived Enjoyment, Mobile Learning Intention
2020	Jaukovic Jocic et al.	Level of content, Presentation method, Teaching method, E-learning environment, Learning materials, Quality of multimedia content, Group work and interactivity
2020	Naveed et al.	Attitude towards e-learning, Motivation of students, General internet self-efficacy, Interaction with other students, Commitment to online studies, Instructors' attitude towards e-learning, Information and Communication Technologies skills, Ease language communication, Appropriate timely feedback, Interactive learning activity, Appropriate course design , Use of multimedia instruction, User-friendly design, Understandable content, Convenient system, Ease of access, Technical support for users, Good internet speed, Efficient technology infrastructure, Reliability, Infrastructure preparation, Financial preparation, Education of users, Faculty support, Ethical and legal issues
2020	Muhammad et al.	Timely, Relevant, Multilanguage, Variety of Presentation, Accuracy, Reliability of Content, Attractive, Appropriateness, Color, Multimedia Elements, Text, Browser Compatibility, Index, Navigation, Consistency, Links, Logo, Domain, User Friendly, Reliability, Availability, Interactive Features.
2020	Korucuk B.	Personal Suitability, Effectiveness, Learning, Program Evaluation, Technology, Material, Evaluation, Support Services
2021	Gong et al.	User Interface, Personalization, Interactivity, Security, Complete Content, Navigation, Right and Understandable Content
2021	Toan et al.	Design, Navigation, Response Rate, Impression Score, User-Friendliness, Interactivity, Connectivity, Security, Right and Understandable Content, Complete Content, Up-to-Date, Ethical and Legal Issues, Variety of Educational Level, Price, Personalization
2021	Siew et al.	Learning and Teaching, Attractiveness, Quality Management System, Information Quality, Flexibility
2021	Alojaiman	Reliability, Updated, Understandability, Timeliness, Accuracy, Visual representation, Security, Loading speed, Accessibility
2021	Güldeş et al.	Framework, Function, Security, Material, Collaboration, Quality, Assessment
2022	Atıcı et al.	Adaptation, Framework, Function, Security, Content, Cooperation and Communication, Quality, Learning, Assessment and Evaluation, Technical Specifications, Support

Chao and Chen (2009) identified five main criteria in their study. Among these criteria, there are five sub-criteria for the e-learning materials criterion, which is also the subject of our study. These are given as ease of use, structure, and contents, contain active and vivid multimedia design, and possess interactive mode and exercise and quizzes. The Consistent Fuzzy Preference Relations (CFPR) method was used in the study.

Alias et al. (2012) identified elements to ensure the success of E-learning. In order to determine the important elements of e-learning based on students' perceptions, a scale was applied to the students, and the obtained data were analyzed using SPSS.

Syamsuddin (2012) used the F-AHP method to determine the quality of e-learning software in his study. The six criteria used in his study have 22 sub-criteria. These six criteria are given in the relevant row in Table 1.

Prougestaporn et al. (2015) identified the criteria that are important for creating an effective e-learning environment that can be used in higher education courses, summarised the main success factors and evaluated the effectiveness of e-learning for higher education. The questionnaire was applied to the participants, and the results were analyzed. Abdel-Gawad and Woollard (2015) examined teacher characteristics (attitude towards e-learning, technology and support competence); students' characteristics (computer proficiency, English language proficiency, and learning style); and technology (usability, facilities, and infrastructure) factors as important criteria for designing a successful e-learning system.

In their literature review conducted in 2016, Zare et al., identified crucial factors for establishing an effective e-learning environment as usability, response time, interactivity, web and course design, accessibility, reliability, cost-effectiveness, functionality, security, stability, trust, accuracy, flexibility, interoperability, and sustainability. Jain et al. (2016) used the distance-based approach (WDBA) method for e-learning system selection and ranking. The most important criteria are listed as up-to-date/full content, correct/intelligible content, and user interface, respectively. Garg (2017) WDBA sought a solution to the E-learning website selection problem using TOPSIS methods. Garg et al. (2018) applied fuzzy COPRAS to evaluate, rank, and select eight e-learning websites based on ten interactive selection indexes.

Khan et al. (2019) used the Proximity Indexed Value (PIV) method in their study. Functionality and sustainability criteria are listed as the two most important criteria. Naveed et al. (2020) evaluated the critical success factors in implementing the e-learning system using multi-criteria decision making. Naveed et al. (2020) also used F-AHP, a multi-criteria decision-making technique, for these five main dimensions and found that the most important main dimension was the corporate governance dimension. Jaukovic Jocic et al. (2020) used Integrated PIPRECIA–Interval-Valued Triangular F-ARAS for e-learning course selection. Gong et al., (2021) listed the evaluation criteria using Linguistic hesitant fuzzy sets (LHFSs) and the TODIM methods. Siew et al. (2021) used the AHP-VIKOR method to select criteria. Alojaiman (2021) has selected an effective e-learning platform using the Hybrid F-AHP-TOPSIS Method. Atici et al. (2022) ranked the criteria using type-2 F-AHP.

Fuzzy Analytical Hierarchy Process (F-AHP)

Fuzzy set theory, developed by Zadeh (1965), allows grading of membership functions. This method aims to mathematically formulate the linguistically expressed variables (Zadeh, 1965). In the classical logic system, if an element belongs to the set, it takes the value of '1'; if it is not a member of that set, it takes the value of '0'. However, in the fuzzy system, the belonging of the elements to the cluster changes between the values of [0-1], in other words, they belong to the cluster at different degrees (Kocakaya et al., 2021).

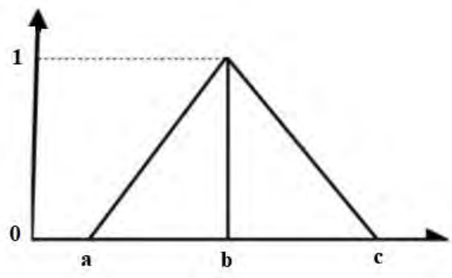
The membership function can be expressed with fuzzy number $\breve{N}$ and triangular fuzzy number as follows (Chou et al., 2019):

$$\mu_{\breve{N}}(x) = \begin{cases} (x-l)/(m-l) & , \quad l \le x \le m \\ (u-x)/(u-m & , \quad m \le x \le u \\ 0 & , \quad others \end{cases}$$

In the function, ‘ l ‘ indicates the lower value, ‘ m ‘ the mean, and ‘ u ‘ is the upper value. Mathematical multiplication, division, and addition operations can be made between two fuzzy numbers.

Figure 1

Triangular fuzzy number diagram.



$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a < x \le b \\ 1, & x = b \\ \dfrac{c-x}{c-b}, & b < x \le c \\ 0, & x \ge c \end{cases}$$

A fuzzy set A in the universal set X is defined as $A = (x, \mu(x); x\epsilon X)$. Here, $\mu_A: A \rightarrow [0,1]$ is the grade of the membership function and $\mu_A(x)$ is the grade value of $x \in X$ in the fuzzy set A (Panda and Pal, 2015).

The important difference between fuzzy logic and other logic systems is that verbal variables can be used. Verbal variables allow for approximate descriptions of concepts that cannot be expressed clearly. Chang (1996) presented a new approach in which F-AHP suggested using triangular fuzzy numbers for pairwise comparison scales and making pairwise comparisons with these numbers and introduced F-AHP. F-AHP is a modified version of the AHP method. Although the purpose of the AHP is to determine the weights of the criteria according to the knowledge of the experts, the traditional AHP may fail to reflect the human thinking style. For this reason, F-AHP, a fuzzy extension of AHP, was developed. F-AHP can produce more accurate results in decision-making (Gnanavelbabu & Arunagiri, 2018). F-AHP uses fuzzy numbers or linguistic expressions (equal importance, absolute importance, etc.) for calculations (Sönmez Çakır & Pekkaya, 2020). F-AHP method applications are carried out in the following steps (Sönmez Çakır & Pekkaya, 2020).

Step 1. Pairwise comparison matrices are created.

$$\tilde{A}^k = \begin{bmatrix} \tilde{d}_{11}^k & \tilde{d}_{12}^k & \cdots & \tilde{d}_{1n}^k \\ \tilde{d}_{21}^k & \tilde{d}_{22}^k & \cdots & \tilde{d}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{d}_{n1}^k & \tilde{d}_{n2}^k & \cdots & \tilde{d}_{nn}^k \end{bmatrix}$$

Fuzzy equivalents of linguistic expressions are used when constructing this matrix. The triangular fuzzy number equivalents of the comparison expressions 1-9 used in the AHP are given in Table 2.

Table 2

Triangular Fuzzy Number

Value	Definition	Triangular fuzzy number
1	Equally important	(1, 1, 1)
3	Moderately important	(2, 3, 4)
5	Strongly important	(4, 5, 6)
7	Very strongly important	(6, 7, 8)
9	Extremely important	(9, 9, 9)
2;4;6;8	Intermediate values	(1, 2, 3); (3, 4, 5); (5, 6, 7); (8, 8, 9)

Step 2. The geometric mean approach is preferred to obtain the fuzzy geometric mean and weights of each criterion. Equation (1) is used for this calculation.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n} \qquad i = 1,2,\ldots,n \qquad (1)$$

Step 3. Fuzzy criterion weights are defined. Equation (2) is used for this calculation.

$$\tilde{w}_i = \tilde{r}_i x(\tilde{r}_i+\ldots+\tilde{r}_n)^{-1} \qquad (2)$$

Step 4. The criterion mean (M_i) and normalized (N_i) weight can be calculated using equations (3) and (4).

$$M_i = (\tilde{w}_1+\ldots+\tilde{w}_n)/n \qquad (3)$$

$$N_i = M_i/(M_1+\ldots+M_n) \qquad (4)$$

The F-AHP method is used in many decision-making problems in the literature. Fuzzy supplier selection (Chan et al., 2008), personnel selection (Güngör et al., 2009), risk analysis (Mangla et al., 2015), resource selection (Wang et al., 2020), risk assessment (Ganguly & Guin, 2013), financial performance assessment (Shaverdi et al., 2014), determining student admission criteria (Kustiyahningsih & Aini, 2020) etc. has found application in many fields.

Method

A quantitative research method was used in the study. The aim was to rank the criteria that affect the selection of e-learning systems and to determine the importance levels of the criteria that guide users and developers. For this purpose, ten criteria were determined by the literature review. The obtained pairwise comparison results were analyzed with the Fuzzy Analytic Hierarchy Process (F-AHP), which is a Multi-Criteria Decision-Making Method (MCDM).

Features of Expert Participants

The 10 criteria used in the research were evaluated and determined through expert opinions. The criteria obtained by the literature review were presented to 18 experts/users in the field, and they were asked to rank them. The 10 criteria with the best ranking among the scores were selected this way. In the AHP method, the number of criteria was kept at this level since there should not be too many criteria in order to ensure consistency in pairwise comparisons. After the criteria were determined, 16 experts were asked to compare the 10 criteria determined. Of these experts, 3 (18.75%) were female (3 computer teachers), 13 (81.25%) were male (4 computer teachers, 6

academicians, 2 software engineers, 1 computer engineers). Also the age range of the participants ranges from 28 to 56.

Data Collection

Before these criteria were included in the pairwise comparison, the experts were asked to rank the criteria from the most important to the least important. This provided the possibility of simultaneous control. Therefore, there is no inconsistency in any of the answers received.

Criterion Features

Interaction (C1): The interaction criterion, when designing the e-learning system, indicates the ability of learners to ask questions to instructors and actively participate in the course.Reliability/Security (C2): It refers to the system's safe operation without any external factor's intervention. At the beginning of the Covid 19 period, a widely used e-learning platform for education was faced with different security vulnerabilities.

Interface/Design (C3): An interface is software that allows user and system communication. The interface visual of the designed platform can be an effective factor for the preference of this systemThe distribution of colors and the locations of the tabs can be taken as criteria for preferability.

Ease of Use (C4): Ease of use of a designed program has been determined as a criterion. It is regarded as an important factor that not only the colors and tabs but also the program user can easily reach the place they want to access the program. Quick access is also included in this criterion.

Flexibility (C5): The flexibility of the platform to be created means that it can be redesigned according to the wishes based on users.

Traceability (C6): An important feature in e-learning programmes is that the courses have a retraceable structure and retraceability is determined as a criterion. In addition, there are flow features such as pause, rewind, etc. within this feature.

Technical Support Service (C7): It is important that users are not victimized in case of any technical problems that may arise and that technical problems are eliminated, especially for live lessons. For this reason, having a support team available was considered a criterion.

Content (C8): Content factor is also considered as an important criterion among the reasons for preferring a platform. The fact that the platform contains information about the subject of interest, that it can direct to other interesting trainings, that the content is up-to-date, etc. are also included in this criterion. The platform must support several languages in order for various users to access the same material on the same platform in today's more globalized society.

Whether Paid or Not (C9): Another feature that those using the platform may be interested in is the price. Subscription requests, inclusion of ads for free programs, etc., are included in this criterion. Some platforms may be paid, while others may be free with advertisements.

Working Offline (C10): The ability to work offline has also been seen as an important criterion for the designed system to be accessible to everyone. Even in places where there is no internet service, users will be able to access training.

Ethical Procedures

In this study, ethics committee approval is required within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive," and all the rules stated to be followed were followed. In the meeting numbered 18 of the Social and Human Sciences Research and Publication Ethics Committee of Bartın University, the application number 2022-SBB-0347 was found to comply with the ethical principles. Ethics Committee Approval is attached.

Results

The pairwise comparison matrix obtained from 16 experts was translated into the fuzzy linguistic equivalents given in Table 2, their geometric averages were taken, and the initial matrix was formed. The first given matrix is the pairwise comparison matrix of the first expert. For example, the fuzzy number equivalent of "5" in the pairwise comparison of the C1 and C2 criteria of the first expert is obtained as (4,5,6). The fuzzy number values to be entered in the pairwise comparison of C2 and C1 for the same expert are (1/6,1/5,1/4). The fuzzy number matrix of the first expert is given in Appendix 1. This matrix is presented in Table 3. Subsequent operations were continued with the general initial matrix formed from geometric means.

Step 1. Pairwise comparison matrices are created

Table 3

Pairwise Comparison Values of the First Expert (1-9 scale)

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1. Interaction	1	5	3	1	7	6	2	2	4	9
C2. Reliability	1/5	1	1/2	1/4	2	1	1/4	1/3	1	2
C3. Interface/Design	1/3	2	1	1/4	3	2	1/3	1	1	5
C4. Ease of Use	1	4	4	1	6	5	2	3	3	7
C5. Flexibility	1/7	1/2	1/3	1/6	1	1	1/5	1/5	1/3	1
C6. Traceability	1/6	1	1/2	1/5	1	1	1/2	1/3	1/2	2
C7. Technical Support Service	1/2	4	3	1/2	5	2	1	2	2	7
C8. Content	1/2	3	1	1/3	5	3	1/2	1	2	4
C9. Whether Paid or Not	1/4	1	1	1/3	3	2	1/2	1/2	1	4
C10. Working Offline	1/9	1/2	1/5	1/7	1	1/2	1/7	1/4	1/4	1

The initial matrix obtained by taking the geometric mean of the opinions of 16 experts according to the fuzzy numbers is given in Table 4. In order to obtain this matrix, all expert opinions were tabulated with their fuzzy number equivalents. Table 4

was obtained by taking the geometric mean of the comparison values of all experts. The complete version of Table 4 is given in Appendix 2.

Table 4

Fuzzy Number Averages of All Expert Opinions (General initial matrix)

	C1			C2			…	C10		
	l	m	u	l	m	u	…	l	m	u
C1	1.00	1.00	1.00	2.17	2.89	3.52	…	6.34	7.11	7.82
C2	0.28	0.35	0.46	1.00	1.00	1.00	…	2.17	2.91	3.57
C3	0.20	0.26	0.37	0.80	0.87	1.00	…	1.68	2.46	3.47
C4	0.49	0.61	0.87	1.43	1.89	2.27	…	3.52	4.72	5.83
C5	0.13	0.14	0.15	0.25	0.33	0.52	…	0.70	0.87	1.15
C6	0.17	0.21	0.27	0.41	0.56	0.79	…	1.32	1.82	2.46
C7	0.20	0.26	0.36	0.58	0.87	1.38	…	1.15	1.70	2.35
C8	0.39	0.46	0.58	0.76	1.15	1.64	…	2.55	3.20	3.81
C9	0.21	0.27	0.39	0.52	0.76	1.05	…	1.97	2.70	3.35
C10	0.13	0.14	0.16	0.28	0.34	0.46	…	1.00	1.00	1.00

Steps 2 and 3. Using Equation (1) and Equation (2), the fuzzy geometric mean and weights of each criterion were obtained. The results are presented in Table 5.

Table 5

Fuzzy Number Averages and Fuzzy Weights of All Expert Opinions

	Geometric Means			Fuzzy Weights		
Criteria	l	m	u	l	m	u
C1. Interaction	2.524	3.241	3.849	0.164	0.266	0.412
C2. Reliability	0.877	1.153	1.499	0.057	0.095	0.160
C3. Interface/Design	0.737	0.952	1.246	0.048	0.078	0.133
C4. Ease of Use	1.564	2.084	2.613	0.102	0.171	0.280
C5. Flexibility	0.335	0.407	0.530	0.022	0.033	0.057
C6. Re-Traceability	0.545	0.687	0.886	0.035	0.056	0.095
C7. Technical Support Service	0.656	0.878	1.185	0.043	0.072	0.127
C8. Content	1.067	1.378	1.736	0.069	0.113	0.186
C9. Whether Paid or Not	0.711	0.925	1.221	0.046	0.076	0.131
C10. Working Offline	0.341	0.422	0.545	0.022	0.035	0.058

Step 4. The criterion means (M_i) and normalized (N_i) weights were calculated using equations (3) and (4) and the obtained values are given in Table 6.

Table 6

The Criterion Means (M_i) and Normalized (N_i) Weights

Criteria	M_i	N_i	Rank
C1. Interaction	0,281	0,260	1
C2. Reliability	0,104	0,096	4
C3. Interface/Design	0,086	0,080	5
C4. Ease of Use	0,184	0,170	2
C5. Flexibility	0,037	0,035	9*
C6. Re-Traceability	0,062	0,058	8
C7. Technical Support Service	0,080	0,074	7
C8. Content	0,123	0,114	3
C9. Whether Paid or Not	0,084	0,078	6
C10. Working Offline	0,038	0,035	9*

*: have the same priority values

When the F-AHP procedures were finalized, the ranking among the criteria became clear.

Ten criteria, created with the criteria obtained through the literature review and the current opinions and suggestions from the experts, were again given to an expert group to make pairwise comparisons. Experts were asked to perform pairwise comparisons with the 1-9 scale given in Table 2. These obtained comparison matrices were converted to fuzzy numerical values given in Table 2. and F-AHP steps were applied. As a result of this application, the Interaction (C1) criterion was obtained as the most important criterion among the ten criteria. Ease of Use (C4), Content (C8), Reliability (C2), Interface/Design (C3), Availability (C9), Technical Support Service (C7), Re-Traceability (C6), Working Offline (C10) and Flexibility (C5). Interaction was found to have the greatest weight with 26% in the ranking. The total weight of the first 4 criteria was 64%. These first four criteria have a 64% effect on the decision. Flexibility, Offline Operation, and Re-Traceability criteria were the three criteria with the lowest weight; their total weight was determined as approximately 1%. These results were compared with the literature, the differences were determined, and the reasons were discussed.

Discussion and Conclusion

With the study, the criteria to be considered in the selection of an e-learning system are listed. According to the results obtained, it is a very important criterion for students to be able to ask questions to the trainers simultaneously and to actively participate in the lesson. This highlights that a designed e-learning system should be interactive. It can be said that during online education periods, live broadcasting during lectures, asking questions, and opening the trainer's camera increase the education's effectiveness. The most important distinction between face-to-face education and e-learning is realized in this criterion. The interaction feature, which can be counted

among the disadvantages of e-learning systems, has also emerged as a very important criterion in system selection. The interaction feature has not been studied much, especially in the pre-Covid period. This study revealed how important the interaction criterion is for e-learning systems, which have become mandatory during the Covid period. The interaction criterion has been found to be effective for the habitual student-teacher relationship to be experienced in these systems, which have become more popular with Covid-19 and are no longer used as a choice but as a necessity. In addition to other criteria, interaction criteria were also sought in distance education for English learning before the epidemic. However, the disappearance of the interaction in the traditional education process for all courses is thought to be very effective in ranking this criterion.

The second criterion is that a designed program is easy to use and understandable by everyone. Accordingly, not only the colors or design on the screen, but also the ease of reaching the desired destination affects the choice of the e-learning system. The fact that it has fast access facilities is also evaluated within this criterion. This criterion appears in many studies in the literature. Alias et al., (2012) ranked first with 70.34% of their study's ease of use criterion. In other studies, this criterion is at the top.

According to experts, among these criteria, content is the other feature that is questioned in a system. The third criterion seems to be that it contains information about the subject it is related to, that it is up-to-date or can be updated, and that it is a guide for other training. One of the ways that education received in the globalizing world is equal and accessible to everyone is that it has content accessible to everyone. Having different language options can make the distribution of education more equitable. Language options are also added to this criterion besides the explanations of other publications in the literature. Jain et al., (2016) stated that the complete and correct content criterion is the most important and gave the highest weight value to it in their article. Alojaiman (2021) claims that content accuracy is the most important criterion in content quality.

One of the system selection criteria is reliability. It is an important factor that it is designed reliability so that it is not open to outside interference. It should be resistant to cyber-attacks, password cracking and system infiltration. The entry of unauthorized persons into the meeting on a platform used during the Covid epidemic caused a significant vulnerability. Upon this situation, the platform has given the meeting owner the authority to take the people they want to the meeting. This criterion is the most used criterion in selecting the e-learning system in the literature review. Alojaiman (2021) claimed that reliability is the second important criterion in content quality. Guldes et al. (2021) stated that the weight of this criterion is higher than the other criteria compared and is the most important criterion. In our study, this criterion took its place at the top.

The interface design or other system design is an important selection criterion. Even in psychological tests, the effects of colors on the human brain are mentioned. At the same time, people want to find the program tabs they use the most more quickly. For this reason, the tabs that are thought to be used the most should be made easier to find or the user should be given the opportunity to be customized, and at the same time, the effects of colors in the design should not be neglected. Shee and Wang (2008) determined the interface criterion as the most important criterion in their study.

Interface criteria in this study: It is divided into sub-dimensions of Ease of use, User-friendliness, Ease of understanding, and Operational stability.

Among the selection criteria, the criterion of whether the application is paid or not was considered important by the experts. It ranked sixth among the top ten criteria. Some programs are sold or used for a fee. How much this fee is a criterion that affects the selection. Advertisements in similar and free programs negatively affect concentration during the lesson. For this reason, systems with reasonable fees and/or few advertisements may be preferred more. Technical support service is also important especially for online platforms. If this technical support program is caused by itself, the system manufacturer is expected to solve the problem. The absence of a service that will interfere with systemic problems will affect the choice.

Re-traceability, offline operation and Flexibility criteria, which are in the last three ranks, are also among the ten most important criteria chosen by experts. Features such as re-watching the lesson, rewinding, slowing down and stopping were important. In places where there is an internet problem or in case of financial difficulties, the ability of the system to work offline can also be taken into account. Personalization is the last among the ten criteria. This feature means the user can shape the system according to their needs and tastes. It was ranked tenth according to other criteria.

When the current ranking of the study is examined, the first five criteria's C1: Interaction (0.260), C4: Ease of Use (0.170), C8: Content (0.114), C2: Reliability/Security (0.096) and C3: Interface (0.080) values and the selection criteria are 0.72. It can be seen that part of current situations may have brought some selection criteria to the fore. However, criteria such as ease of use, content, reliability are still at the top.

It should not be forgotten that there are different criteria apart from these, but these have been examined since they are among the first ten criteria among the criteria. Student preferences, location, internet infrastructure, computer literacy knowledge are among the other criteria that can be listed in the system selection. The results obtained can be used directly to evaluate e-learning systems and provide important information to designers and users to improve e-learning application.

It is very important to adapt to the requirements of the age for e-learning systems that have developed over the years and technology advances. Many studies have been done on this before the Covid process, but this process has revealed more clearly the need for e-learning systems. The results obtained may differ according to the countries and the infrastructure characteristics of the countries. For example, offline working can be achieved as a higher criterion where internet infrastructure is not developed. As in many studies, ease of use, content and reliability were at the top in this study.

Implications

Differences can be obtained even if the same methods are used in the ranking results obtained in this and similar studies. The most important reasons are; the characteristics of the environment, the characteristics of the country where the study was conducted, and the differences of opinion of the experts participating in the study. E-learning systems, which were also used in the pre-Covid-19 period, were not used as a necessity at that time. In other words, people preferred one of these systems with their

preferences. However, using these systems has become mandatory during and after the Covid-19 period. For this reason, the order of the criteria may differ in the studies before and after the pandemic. While offline work is an important criterion in studies conducted in countries with poor internet infrastructure, it is natural that this criterion does not rank high in countries that do not have infrastructure problems. In societies accustomed to face-to-face education, it may become important for e-learning systems to be interactive. When the studies were examined, the security and content criteria were obtained as an important criterion in almost all studies. We can say that these two features are indispensable features of the e-learning system. For these reasons, this study reflects the views in Turkey and the post-Covid-19 situation.

Statement of Responsibility

Yasemin SÖNMEZ GÜMÜŞHAN; Literature review, data collection and data entry, writing the conclusion.

Fatma SÖNMEZ ÇAKIR; Literature review for analysis, analysis of expert opinions, data analysis and interpretation, writing the conclusion.

Conflicts of Interest

This research has no financial, commercial, legal or professional relationship with other organizations or those working with them. There is no conflict of interest that would affect the research.

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Appendix 1. First Expert Pairwise Comparison Matrix

Expert 1	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10		
C1	1,00	1,00	1,00	4,00	5,00	6,00	2,00	3,00	4,00	1,00	1,00	1,00	6,00	7,00	8,00	5,00	6,00	7,00	1,00	2,00	3,00	1,00	2,00	3,00	3,00	4,00	5,00	9,00	9,00	9,00
C2	0,17	0,20	0,25	1,00	1,00	1,00	0,33	0,50	1,00	0,20	0,25	0,33	1,00	2,00	3,00	1,00	1,00	1,00	0,20	0,25	0,33	0,25	0,33	0,50	1,00	1,00	1,00	1,00	2,00	3,00
C3	0,25	0,33	0,50	1,00	2,00	3,00	1,00	1,00	1,00	0,20	0,25	0,33	2,00	3,00	4,00	1,00	2,00	3,00	0,25	0,33	0,50	1,00	1,00	1,00	1,00	1,00	1,00	4,00	5,00	6,00
C4	1,00	1,00	1,00	3,00	4,00	5,00	3,00	4,00	5,00	1,00	1,00	1,00	5,00	6,00	7,00	4,00	5,00	6,00	1,00	2,00	3,00	2,00	3,00	4,00	2,00	3,00	4,00	6,00	7,00	8,00
C5	0,13	0,14	0,17	0,33	0,50	1,00	0,25	0,33	0,50	0,14	0,17	0,20	1,00	1,00	1,00	1,00	1,00	1,00	0,17	0,20	0,25	0,17	0,20	0,25	0,25	0,33	0,50	1,00	1,00	1,00
C6	0,14	0,17	0,20	1,00	1,00	1,00	0,33	0,50	1,00	0,17	0,20	0,25	1,00	1,00	1,00	1,00	1,00	1,00	0,33	0,50	1,00	0,25	0,33	0,50	0,33	0,50	1,00	1,00	2,00	3,00
C7	0,33	0,50	1,00	3,00	4,00	5,00	2,00	3,00	4,00	0,33	0,50	1,00	4,00	5,00	6,00	1,00	2,00	3,00	1,00	1,00	1,00	1,00	2,00	3,00	1,00	2,00	3,00	6,00	7,00	8,00
C8	0,33	0,50	1,00	2,00	3,00	4,00	1,00	1,00	1,00	0,25	0,33	0,50	4,00	5,00	6,00	2,00	3,00	4,00	0,33	0,50	1,00	1,00	1,00	1,00	1,00	2,00	3,00	3,00	4,00	5,00
C9	0,20	0,25	0,33	1,00	1,00	1,00	1,00	1,00	1,00	0,25	0,33	0,50	2,00	3,00	4,00	1,00	2,00	3,00	0,33	0,50	1,00	0,33	0,50	1,00	1,00	1,00	1,00	3,00	4,00	5,00
C10	0,11	0,11	0,11	0,33	0,50	1,00	0,17	0,20	0,25	0,13	0,14	0,17	1,00	1,00	1,00	0,33	0,50	1,00	0,13	0,14	0,17	0,20	0,25	0,33	0,20	0,25	0,33	1,00	1,00	1,00

Appendix 2. Fuzzy number averages of all expert opinions (General initial matrix) Complete Version

	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10		
C1	1,00	1,00	1,00	2,17	2,89	3,52	2,37	3,57	4,66	1,15	1,64	2,05	6,51	7,24	7,92	3,73	4,84	5,90	2,64	3,76	4,82	1,72	2,17	2,54	2,55	3,73	4,75	6,34	7,11	7,82
C2	0,28	0,35	0,46	1,00	1,00	1,00	1,00	1,15	1,25	0,44	0,53	0,70	1,93	3,03	4,08	1,27	1,78	2,43	0,72	1,15	1,72	0,58	0,82	1,22	0,95	1,32	1,93	2,17	2,91	3,57
C3	0,20	0,26	0,37	0,80	0,87	1,00	1,00	1,00	1,00	0,37	0,48	0,61	1,64	2,40	3,06	1,00	1,32	1,90	0,85	1,18	1,74	0,53	0,67	0,82	0,64	0,92	1,39	1,68	2,46	3,47
C4	0,49	0,61	0,87	1,43	1,89	2,27	1,64	2,09	2,72	1,00	1,00	1,00	3,23	4,44	5,56	2,17	3,31	4,38	1,64	2,76	3,82	1,15	1,58	2,05	1,64	2,11	2,49	3,52	4,72	5,83
C5	0,13	0,14	0,15	0,25	0,33	0,52	0,33	0,42	0,61	0,18	0,23	0,31	1,00	1,00	1,00	0,53	0,67	0,82	0,31	0,38	0,53	0,24	0,29	0,37	0,35	0,45	0,64	0,70	0,87	1,15
C6	0,17	0,21	0,27	0,41	0,56	0,79	0,53	0,76	1,00	0,23	0,30	0,46	1,22	1,50	1,89	1,00	1,00	1,00	0,66	0,80	1,00	0,45	0,54	0,66	0,58	0,76	1,00	1,32	1,82	2,46
C7	0,20	0,26	0,36	0,58	0,87	1,38	0,57	0,85	1,18	0,26	0,36	0,61	1,89	2,61	3,25	1,00	1,25	1,52	1,00	1,00	1,00	0,47	0,66	1,00	0,83	1,08	1,32	1,15	1,70	2,35
C8	0,39	0,46	0,58	0,76	1,15	1,64	1,22	1,50	1,89	0,47	0,61	0,83	2,70	3,45	4,10	1,52	1,86	2,24	1,00	1,52	2,14	1,00	1,00	1,00	1,06	1,64	2,22	2,55	3,20	3,81
C9	0,21	0,27	0,39	0,52	0,76	1,05	0,72	1,08	1,57	0,40	0,47	0,61	1,57	2,21	2,86	1,00	1,32	1,72	0,76	0,92	1,20	0,45	0,61	0,94	1,00	1,00	1,00	1,97	2,70	3,35
C10	0,13	0,14	0,16	0,28	0,34	0,46	0,29	0,41	0,60	0,17	0,21	0,28	0,87	1,15	1,43	0,41	0,55	0,76	0,43	0,59	0,87	0,26	0,31	0,39	0,30	0,37	0,51	1,00	1,00	1,00