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Assessment Factors Affecting E-Learning Using Fuzzy Analytic Hierarchy Process and SWARA*

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The importance of distance education has increased due to its many advantages. At the same time, apart from university education, distance education also allows oneself to develop in different subjects. This work examines a distance education study conducted at a university in Turkey. The Department of Industrial Engineering was selected for this study. E-learning applications for industrial engineering education are seen to be extremely efficient, especially since they do not require laboratory applications. The Faculty of Engineering, which aims to obtain a higher quality education of students who receive industrial engineering training through e-learning, has evaluated related software companies in this regard. The infrastructure of the program has been determined as online and recorded broadcasting. Web-based training has been carried out by creating wide communication networks. This study explores in detail the necessary requirements for the successful execution of distance education in industrial engineering. In addition, it has benefited from the work undertaken in the past in order to determine the assessment factors. These assessment factors consist of five main factors and twenty-four sub-factors. These assessment factors have been established in line with the opinions of the people who constitute the infrastructure of this study. These past evaluations were usually made subjectively. Subjective evaluations often cause misinterpretation of results. This study applies both analytic hierarchy process (AHP) and step-wise weight assessment ratio analysis (SWARA) methods, both of which are multiple criteria decision-making methods. Consistency ratios are calculated to determine whether comparisons are consistent for the AHP method. In addition, the AHP method is discussed together with fuzzy logic to make the study more realistic. Due to the ease of application and common use, triangular fuzzy numbers are preferred as a fuzzy method. The results are validated by the SWARA method, which is used to weight the criteria. The purpose of this study is to weight the assessment factors affecting e-learning technology by using fuzzy AHP and SWARA methods. Thus, the study illustrates that multi-criteria decision-making methods can be used in e-learning applications to evaluate many factors.

Keywords: assessment factors; consistency ratio; e-learning; fuzzy analytical hierarchy process; SWARA

1. Introduction

Today's developing technology offers positive contributions to human life. Especially with the development of the Internet, this contribution has gained momentum. In the past, it was extremely difficult to find information. It is now easier to access information with the development of the Internet. Thanks to the Internet, information can be accessed within seconds from everywhere in the world. This development has increased the use of computers. At the same time, this ensures that education is now delivered via the Internet.

There is currently a deficiency in the conducted studies regarding the evaluation of e-learning technology in the engineering education. It is suggested that using fuzzy AHP and SWARA methods to assess the factors affecting the success of the e-learning technology used for education in the Department of Industrial Engineering has not been evaluated in the existing literature. There is a lack of papers including any evaluation for education by e-learning technology as well as e-learning technology in engineering education in general. Lacking the evaluations restricts the content of the studies and leads to wrong assessments. For this reason, it is necessary to correctly determine the factors affecting the success of the e-learning technology.

E-learning is preferred because of its use of flexible and wider information [1] and it has positive effects on students [2]. On the other hand, [3] claim that e-learning education including technological and social methods has encountered feedback problems. In addition to this, e-learning technology is costly; it needs maintenance, upgrading and backing up [4]. It enables ease of use for the students [5].

The factors affecting the success of e-learning are content and interface design, interaction and flexibility [6]. According to [7], the factors affecting the success of e-learning are technical skill, access to technology, motivation and attitude, ease of use, interface and evaluation. [8] mention that e-learning provides usability, effectiveness and satisfaction regarding learning among university students. The effect values of these factors are determined by the survey. The effect values of these are 0.414, 0.275, 0.381 and 0.284, respectively. Each factor in the success of the e-learning technology does not have the same importance in terms of customers and the

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providers. Thus, these factors should be determined.

Apart from the other paper in the literature, this study aims to determine the degree of importance of each factor. For this, this study presents a novel approach that is based on SWARA and fuzzy AHP methods in determining the weights of these factors. First of all, five main factors are weighted by the fuzzy AHP method. Then sub-factors, of which there are twenty-four, are weighted by the fuzzy AHP method. Since the fuzzy AHP method decreases human judgements, we prefer the fuzzy AHP method rather than the AHP method. After that, the criteria are weighted by the SWARA method. Thus, the results are compared.

E-learning technology has improved day-by-day. So, the current state should be examined to contribute to this development. Correct evaluations help to improve e-learning technology and tackle problems. In addition, this enables personnel resources to be identified for current or potential problems, while determining the importance degree of these factors. Beyond these, it is revealed that different disciplines can be used in determining the factors affecting e-learning technology. Both methods present an objective evaluation that allows action to be taken rapidly to address problems because it is easy to use. Since e-learning technology has developed rapidly, it should make decisions rapidly to keep up with this development. In addition, this study presents priorities for its development by determining the important issues for e-learning technology. Thus, it offers to create correct strategies for this issue. These developments present advantages for university students in terms of usage. Furthermore, these methods give point of view numerical evaluation of education. It ensures to consider from a different aspect.

This paper was conducted to determine the degree of importance of the varying factors affecting the success of e-learning technology used for education in the Department of Industrial Engineering. In this study, infrastructure, content, learner interface, quality and techniques, which consist of five main factors and include twenty-four sub-factors, have been examined. Fuzzy logic has also adopted to obtain more realistic outcomes. The main factors and sub-factors are weighted by the fuzzy AHP method. The SWARA method is applied to validate the results of the fuzzy AHP method.

The remainder of the paper is structured as follows. In the second section, the related literature review is addressed. In the third section, research focus and scope are discussed briefly. In the fourth section, the methodology is explained and the concepts of the fuzzy AHP and SWARA methods are introduced. In the fifth section, an application weighting the success of the factors affecting e-learning technology in the Department of Industrial Engineering is realized. In the last section, the concluding remarks and the proposals for further studies are made.

2. Brief literature review

Although the literature review shows that there are a lot of studies regarding both fuzzy AHP and SWARA methods, there is a gap in the literature in terms of evaluating e-learning technology in engineering education. The fuzzy AHP method used in this paper is applied to solve multiple criteria decision-making problems in many sectors. These sectors are the healthcare sector [9], the public sector [10], the manufacturing sector [11], education sector [12] and information technology sector [13]. However, there are very few studies about the SWARA method in comparison with the AHP method because the SWARA method is new.

Consequently, no paper was identified in the e-learning education sector that addresses the methods mentioned above. The factors affecting the success of primary school students in mainstream schools are only evaluated by the fuzzy AHP method [12]. Assessment factors and the scope of the subject are different from this method and there is no study using both the fuzzy AHP and SWARA methods based on e-learning education. Fuzzy AHP and SWARA methods, including verbal and numerical assessment, take a broad perspective when considering the performance of e-learning technology in this study.

Nowadays, e-learning is implemented in many sectors. It allows lecturers to update content for education in medical areas [14]. It is shown that e-learning is an effective tool in surgical education [15]. Education on process ulcers for undergraduate students is more effective than traditional education [16]. Requirements for cancer patients are defined as a flexible [17]. It helps nurses to progress and to be more effective [18]. It increases quality in sport training [19] and SMEs [20]. It facilitates students' learning [21]. The use of technology for education and training becomes more widespread every day. E-learning provides interactions between teachers and students [22]. According to [23], a study conducted at the Department of Electrical Power Engineering in Romania illustrates that the performance of e-learning education is higher than that of traditional education [24]. Similarly, another study in Tehran Alzahra University shows that e-learning has positive effects on students' motivation [25]. It develops students' motivation [26]. It increases students' information retrieval skills [27], and it also contributes to students' learning styles [28] and cognitive skills [29]. [30] stress e-learning's implementations for lower secondary school in Slovenia. An e-learning study conducted at the Masaryk University also demonstrates that e-learning allows the presentation of wider content, economic gains, shared courses on further topics, self-help, and specific development for students and plagiarism control; further, it does not require teaching staff, and it is reliable and comfortable to use [31]. Computional programs are used for engineering education in Mexico [32].

3. Research focus and scope

There are a lot of papers that address the importance of e-learning education. On the other hand, the factors affecting the quality of this education are not numerically assessed. Today, numerical analysis has gradually become crucial. In addition to this, the factors that are used to assess this importance do not have equal significance. This study can measure these factors numerically. The most common method for the weighting is fuzzy AHP, as the SWARA weighting method is relatively new. In this study, fuzzy AHP and SWARA methods are applied to weight the success of the factors affecting e-learning technology in the Department of Industrial Engineering. Fuzzy AHP method results are compared to SWARA method results for validation. According to five experts' viewpoints, the evaluations have been conducted. This method can be applied in varied studies for education. In addition, this paper is able to take precautions for the defects occurring in terms of the factors' degree of importance in e-learning technology.

4. Methodology

The steps of this paper are as follows: first of all, a fuzzy AHP method structure is determined and then five experts are selected for assessment. The purpose of this study is first explained to the five people who carried out the application. A fuzzy extent analysis method containing triangular fuzzy numbers is adopted as a fuzzy method since it is easy to implement. This method is developed by Chang [33] and is most often applied. The linguistic values transform into triangular fuzzy numbers, as shown in Table 3 and Table 4. Firstly, pairwise comparisons are done for the five main factors. Then, sub-factors are similarly compared with each other for each main factor. Similarly, the SWARA method based on pairwise comparisons is performed to weight main factors and sub-factors. Twenty-four factors based on five main factors are scored in line with five experts' viewpoints with regard to triangular fuzzy numbers and the SWARA method. Therefore, main factors and sub-factors are weighted for industrial engineering education. These factors are infrastructure (C1), content (C2), learner interface (C3), quality (C4), and techniques (C5). The infrastructure consists of four sub-criteria: web & course design (c11), virtuality (c12), easy to monitor the students (c13), easy to measure the exam results (c14). The content consists of four sub-criteria: rich content (c21), content update (c22), useful content (c23) and content legibility (c24). Following that, the learner interface consists of eight sub-criteria: easy to use (c31), easy to access (c32), easy to be flexible (c33), easy to access shared data (c34), easy to interact with other students (c35), easy to interact with lecturers (c36), operational stability (c37) and interoperability (c38). Then, the quality consists of four sub-criteria: response time (c41), cost-effectiveness (c42), accuracy (c43), and continuity (c44). Finally, the techniques consist of four sub-criteria: reliability (c51), technical support (c52), trust (c53), and easy to maintain (c54). These factors are then grouped among themselves. Determining the importance ratings of the factors affecting distance education will shed some light on which topics are emphasized the most for future studies. Thus, it is aimed to measure the effectiveness of distance education. There are many evaluations to build the weight of the criteria. However, any misjudgement leads to misinterpretation of the assessment of the effectiveness of distance education. Misinterpreting also changes the priorities of the precautions to be taken.

4.1 Fuzzy analytic hierarchy process method

In this study, AHP is fulfilled to weight the criteria. AHP with fuzzy logic has been fulfilled to attain realistic results. The AHP method contains verbal and numerical techniques and determines the weight of criteria utilizing pairwise comparison [34]. Conventional AHP is widened as fuzzy AHP. Fuzzy AHP contains the following steps [33]:

Step 1: specifying experts to evaluate.

Step 2: choosing the fuzzy AHP method.

Step 3: specifying factors and determining a fuzzy scale. Verbal importance is shown in Table 1.

Extending the fuzzy method to include triangular values, as improved by Chang (1996), is preferred, since it is easy to implement.

Step 4: converting fuzzy triangle values to pairwise comparison values.

Step 5: applying pairwise comparisons (according to Table 1, pairwise comparisons are conducted).

Step 6: calculating the Consistency Ratio (CR) in terms of pairwise comparisons.

Table 1. Linguistic terms and fuzzy importance values used in pairwise comparisons [35]

Verbal Importance	Fuzzy Numbers	Scale Values
Equally important (E)	(1,1,1)	(1/1,1/1,1/1)
Intermediate values (EI)	(1,2,3)	(1/3,1/2,1/1)
Moderately important with one over another (M)	(2,3,4)	(1/4,1/3,1/2)
Intermediate values (MI)	(3,4,5)	(1/5,1/4,1/3)
Strongly important (S)	(4,5,6)	(1/6,1/5,1/4)
Intermediate values (SI)	(5,6,7)	(1/7,1/6,1/5)
Very strongly important (VS)	(6,7,8)	(1/8,1/7,1/6)
Intermediate values (VSI)	(7,8,9)	(1/9,1/8,1/7)
Extremely important (EX)	(8,9,9)	(1/9,1/9,1/8)

Table 2. Random index [33]

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Pairwise comparisons are updated if the CR is higher than 0.1. Pairwise comparisons are applied in the matrix, and then consistency has been calculated in Equation (1) and Equation (2). The Consistency Index (CI) and the Random Index (RI), which are shown in Table 2, are utilized in calculating the CR.

$$\text{Consistency Index CI} = (\lambda_{max} - n)/(n-1) \quad (1)$$

$$\text{Consistency Ratio CR} = \text{Consistency Index (CI)/Random Index (RI)} \quad (2)$$

If Step 6 results are not consistent, Step 5 is repeated.

Step 7: implementing the fuzzy AHP method based on triangular fuzzy values $X = \{x_1, x_2, ..., x_n\}$ objects cluster and $U = \{u_1, u_2, ..., u_n\}$ target cluster. Thus, m extended analysis values for each object is represented by Equation (3):

$$M^1_{g_i}, M^2_{g_i}, ..., M^m_{g_i}, i = 1, 2, ..., n \quad (3)$$

Step 7.1: According to the i^{th} object, fuzzy artificial size values (Equation (4) and Equation (7)):

$$s_i \sum_{j=1}^{m} M^j_{g_i} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{g_i}\right]^{-1} \quad (4)$$

$$\sum_{j=1}^{m} M^j_{g_i} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (5)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{g_i} = \left(\sum_{i=1}^{n} l_j, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_j\right) \quad (6)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{g_i}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_j}, \frac{1}{\sum_{i=1}^{n} m_j}, \frac{1}{\sum_{i=1}^{n} l_j}\right) \quad (7)$$

Step 7.2: $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ probability value (Equation (8) and Equation (9)):

$$V(M_2 \geq M_1) = [\min(\mu_{M_1}(x), \mu_{M_{21}}(y))] \quad (8)$$

$$V(M_2 \geq M_1) = \begin{cases} 1, & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \end{cases} \quad (9)$$

Step 7.3: The probability of a fuzzy number is greater than other fuzzy numbers $M_i (i = 1, 2, ..., k)$ and the weighting vector (Equation (10) and Equation (12)):

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1), (M \geq M_2), ..., (M \geq M_k)] = \min V(M \geq M_i), \; i = 1, 2, 3, ..., k \quad (10)$$

$$d'(A_i) = \min V(S_i \geq S_k) \text{ for each } k = 1, 2, ..., n; k \neq i \quad (11)$$

$$\text{Weighting vector } W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \quad (12)$$

Step 7.4: Practicing Normalization Weighting Vector (Equation (13)):

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \quad (13)$$

4.2 SWARA method

Karsuliene et al. (2010) developed the SWARA method. It is related to its probability of predicting decision makers' viewpoints to determine degrees of importance [36]. There are SWARA applications for different sectors such as energy [37], architectural [36] and machine tool sectors [38]. The SWARA method consists of the following steps:

Step 1: ranking criteria in descending order in terms of their anticipated importance.

Step 2: specifying relative importance levels for each criterion starting from the second criterion.

For this, *j* criterion is compared with the previous criterion $(j-1)$. This ratio is expressed as the comparative importance of average values, s_j.

Step 3: specifying the coefficient k_j as follows:

$$k_j = \begin{cases} 1 & j = 1 \\ s_j & j > 1 \end{cases} \tag{14}$$

Step 4: specifying the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{k_{j-1}}{k_j} & j > 1 \end{cases} \tag{15}$$

Step 5: specifying degree of criteria's' importance as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{16}$$

Table 3. Pairwise comparisons for decision makers

Decision Makers	**Main Factors**	**C1**	**C2**	**C3**	**C4**	**C5**			
Main Factors	C1	E	E,E,E,E,E	1/EI,1/EI, 1/EI,E,1/EI	1/EI,E,1/EI,E,1/EI	E,E,EI,E,1/EI			
	C2		E	1/EI,1/EI,1/EI, 1/EI,1/EI	1/EI,1/EI, 1/EI,1/EI,1/EI	E,E,E,1/EI,1/EI			
	C3			E	E,EI,EI,EI,EI	E,E,E,E,E			
	C4				E	E,E,E,E,E			
	C5					E			
Sub Factors (C1)	C1	C11	C12	C13	C14				
	C11	E	E,E,E,E,E	EI,E,EI,E,E	M,E,EI,EI,E				
	C12		E	E,E,E,E,E	EI,E,EI,E,E				
	C13			E	E,E,E,E,E				
	C14				E				
Sub Factors (C2)	C2	C21	C22	C23	C24				
	C21	E	E,E,E,E,E	E,1/EI,E,E,E	EI,EI,E,E,EI				
	C22		E	E,E,E,E,E	EI,EI,E,EI,EI				
	C23			E	E,E,E,E,E				
	C24				E				
Sub Factors (C3)	C3	C31	C32	C33	C34	C35	C36	C37	C38
	C31	E	MI,E,M,EI,EI,EI	EI,E,E,1/EI,1/EI,1/EI	M,E,EI,EI,EI,E	M,E,EI,EI,EI,EI	M,E,EI,EI,EI,E	M,E,EI,EI,EI,EI	M,E,EI,EI,EI,E
	C32		E	1/M,E,1/EI,1/EI,1/EI,	1/EI,E,E,E,E	1/EI,E,E,E,E	1/EI,E,E,E,E	1/EI,E,E,E,E	1/EI,E,E,E,E
	C33			E	EI,E,E,E,E	EI,E,E,E,E	EI,E,E,E,E	EI,E,EI,EI,EI	EI,E,EI,EI,EI
	C34				E	E,E,E,E,E	E,E,E,E,E	E,E,E,E,E	E,E,E,E,E
	C35					E	E,E,E,E,E	E,E,E,E,E	E,E,E,E,E
	C36						E	EI,E,E,E,E	EI,E,E,E,E
	C37							E	E,E,E,E,E
	C38								E
Sub Factors (C4)	C5	C51	C52	C53	C54				
	C51	E	M,E,EI,M,M	EI,E,E,EI,EI	E,E,E,E,E				
	C52		E	1/EI,E,1/EI,1/EI,1/EI	1/EI,E,1/EI,1/EI,1/EI				
	C53			E	E,E,E,E,E				
	C54				E				
Sub Factors (C5)	C5	C51	C52	C53	C54				
	C51	E	E,E,E,E,1/EI	EI,E,EI,E,EI	E,E,EI,E,E				
	C52		E	EI,E,EI,E,EI	E,E,EI,E,E				
	C53			E	E,E,E,E,E				
	C54				E				

Here, w_j denotes the importance degree of *j-th* criterion, and *n* denotes number of criteria.

5. Application of the fuzzy AHP and SWARA to e-learning technology

This paper measured the quality of service in terms of the success of the factors affecting e-learning technology in the Department of Industrial Engineering. When conducting a study about e-learning technology, unnecessary issues can be focussed on, thus existing human resources lead to mislead. Therefore, the fuzzy AHP method has been performed to specify the importance weights of the factors affecting the success of e-learning technology. The five perspectives determined by fuzzy AHP are infrastructure (C1), content (C2), learner interface (C3), quality (C4) and techniques (C5). Pairwise comparisons of the factors for decision makers are shown in Table 3. The CR is calculated whether pairwise comparisons are correct or not in terms of technical accuracy. The CR in C1 for the five experts are 3.01%, 0.00%, 2.248%, 2.247%, and 0.00%; the CR in C2 for the five experts are 2.25%, 6.86%, 0.00%, 2.247%, and 2.25%; the CR in C3 for the five experts are 0.004%, 0.00%, 0.009%, 2.06%, and 3.04%; the CR in C4 for the five experts are 0.004%, 0.00%, 0.009%, 2.06%, and 3.04%; the CR in C5 for the five experts are 2.25%, 0.00%, 0.00%, and 0.00%, and 4.5%; and the CR in the main factors for the five experts are 1.73%, 2.61%, 6.24%, 2.64%, and 1.3%. The CRs are less than 10%; pairwise comparisons are validated in terms of technical accuracy. According to the fuzzy AHP method, the weights of the factors are shown in Table 4. The outcomes in Table 4 demonstrate that

Table 4. Global weights of the factors for fuzzy AHP method

Main Factors	Ratio (%)	Sub-factors	Ratio (%)	Global Weights (%)	Ranking
Physical Features (C1)	13.88	C11	44.93	6.23	7
		C12	29.47	4.09	10
		C13	15.26	2.12	19
		C14	10.34	1.44	22
Reliability (C2)	11.91	C21	29.24	3.48	11
		C22	34.49	4.11	9
		C23	23.12	2.75	14
		C24	13.15	1.57	21
Eagerness (C3)	30.51	C31	29.25	8.92	2
		C32	04.62	1.41	23
		C33	24.69	7.53	3
		C34	08.08	2.47	16
		C35	07.99	2.44	17
		C36	10.16	3.10	13
		C37	07.60	2.32	18
		C38	07.60	2.32	18
Confidence (C4)	25.35	C41	37.94	9.62	1
		C42	07.63	1.93	20
		C43	26.09	6.61	5
		C44	28.34	7.19	4
Empathy (C5)	18.35	C51	32.10	5.89	8
		C52	35.89	6.59	6
		C53	14.53	2.67	15
		C54	17.47	3.21	12

Table 5. Comparative importance of main criteria by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C3	-	C3	-	C3	-	C4	-	C3	-
2	C4	0.2	C5	0.2	C4	0.05	C3	0.1	C4	0.15
3	C5	0.25	C4	0.05	C5	0.15	C1	0.2	C5	0.4
4	C1	0.2	C2	0.2	C2	0.4	C5	0.05	C1	0.05
5	C2	0.1	C1	0.05	C1	0.05	C2	0.15	C2	0.15

Table 6. Comparative importance of sub-criteria of first criterion by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C1	-	C2	-	C1	-	C1	-	C1	-
2	C2	0.5	C1	0.05	C2	0.45	C2	0.35	C2	0.4
3	C3	0.6	C3	0.45	C3	0.3	C3	0.35	C4	0.4
4	C4	0.3	C4	0.45	C4	0.35	C4	0.55	C3	0.05

Table 7. Comparative importance of sub-criteria of second criterion by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C2	-	C2	-	C2	-	C1	-	C2	-
2	C1	0.2	C1	0.15	C1	0.3	C2	0.15	C1	0.25
3	C3	0.3	C3	0.25	C3	0.3	C4	0.2	C3	0.25
4	C4	0.4	C4	0.3	C4	0.45	C3	0.1	C4	0.3

Table 8. Comparative importance of sub-criteria of third criterion by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C1	-	C3	-	C1	-	C3	-	C1	-
2	C3	0.45	C1	0.05	C3	0.25	C1	0.05	C3	0.35
3	C6	0.8	C6	0.55	C6	0.65	C6	0.75	C6	0.85
4	C5	0.1	C5	0.15	C5	0.1	C4	0.1	C4	0.05
5	C4	0.05	C4	0.05	C4	0.1	C5	0.05	C5	0.05
6	C7	0.05	C8	0.05	C8	0.05	C7	0.1	C8	0.05
7	C2	0.05	C7	0.05	C7	0.05	C2	0.05	C7	0.05
8	C8	0.2	C2	0.25	C2	0.15	C8	0.25	C2	0.15

Table 9. Comparative importance of sub-criteria of fourth criterion by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C1	-	C1	-	C1	-	C4	-	C1	-
2	C4	0.6	C4	0.55	C4	0.7	C1	0.45	C4	0.55
3	C3	0.05	C2	0.15	C3	0.05	C3	0.1	C3	0.05
4	C2	0.65	C3	0.05	C2	0.55	C2	0.55	C2	0.8

Table 10. Comparative importance of sub-criteria of fifth criterion by decision makers

Importance Rank	DM1		DM2		DM3		DM4		DM5	
	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj	Rank	Sj
1	C2	-	C1	-	C1	-	C2	-	C2	-
2	C1	0.2	C2	0.05	C2	0.1	C1	0.15	C1	0.25
3	C4	0.55	C4	0.45	C3	0.65	C4	0.5	C3	0.45
4	C3	0.15	C3	0.2	C4	0.05	C3	0.15	C4	0.1

learner interface is most important main factor, followed by quality. Content is the least important main factor. In addition, when probing the degree of importance of sub-factors in the way of global weights, this ranking is validated. When examining sub-factors, response time is the most important factor, followed by easy to use; easy to be flexible and continuity also follow it. The results show that easy to use and response time are very important for university students' education. The same perspectives are weighted by the SWARA method. According to Steps 1 and 2, the evaluations are in Table 5 and Table 10. The weights of the factors are in Table 11 for the SWARA method. The weights of main factors are very similar for both methods, and there is the same-ordering in main factors for both methods. The weights of sub-factors are similar in terms of ranking and weights. Effectiveness of these factors directly affects students' interest. This positively affects the success of the students. Focussing

Table 11. Global weights of the factors for SWARA method

Main Factors	Ratio (%)	Sub-factors	Ratio (%)	Global Weights (%)	Ranking
Physical Features (C1)	15.89	C11	37.14	5.90	5
		C12	28.27	4.49	10
		C13	19.57	3.11	16
		C14	15.02	2.39	21
Reliability (C2)	13.93	C21	28.59	3.98	11
		C22	32.68	4.55	9
		C23	20.55	2.86	17
		C24	18.18	2.53	19
Eagerness (C3)	28.15	C31	23.37	6.58	2
		C32	07.94	2.23	23
		C33	19.92	5.61	6
		C34	09.96	2.80	18
		C35	10.15	2.86	17
		C36	11.38	3.20	15
		C37	08.95	2.52	20
		C38	08.33	2.35	22
Confidence (C4)	23.76	C41	35.71	8.48	1
		C42	15.35	3.65	12
		C43	22.51	5.35	8
		C44	26.43	6.28	3
Empathy (C5)	18.27	C51	30.41	5.56	7
		C52	32.95	6.02	4
		C53	17.74	3.24	14
		C54	18.91	3.45	13

on these important factors increases the quality of education.

6. Conclusion and limitations

This paper has measured the degree of importance of the factors affecting the success of e-learning technology used in the Department of Industrial Engineering. The AHP and SWARA methods were preferred to specify the weights of the factors. Fuzzy logic was adopted to obtain more realistic outcomes and because it is less subjective than the AHP method. According to experts, five main factors and 24 sub-factors, including these main factors, depending on triangular fuzzy values were assessed by the fuzzy AHP method. Following that, the SWARA method was performed for the factors. While developing e-learning technology, knowing importance degree of the factors about it enables to prioritize for taking action. It can also be concluded that each factor has a different degree of importance. Using fuzzy AHP and SWARA methods prevented subjective assessments of the factors. The SWARA method was applied to prove the validity of fuzzy AHP results, as it is a novel approach for assessing factors affecting e-learning education. Thus, the development of e-learning education contributes to the development of engineering education systems owing to reliable assessment. Consequently, this method can lead to taking different actions for the development of e-learning education. This study has shed light on processes to improve studies that will be conducted in the field of e-learning. Important factors in terms of students have been determined and this paper will lead to improvements in these matters. Thus, the interest and the success of the students can advance e-learning education by increasing student satisfaction. This paper suggests that everybody can easily perform this method. In future studies, the weights of the factors may be determined by the other methods. This paper can also be conducted in various educational studies.

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