Assessing the Maturity for Digital Education with HFL DEMATEL-HFL ARAS Techniques

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Abstract*. The advances in digital technologies transforms the nature of society. In order to be successful in the connected and complex world that faces fast changes, educational institutions should integrate and use digital technologies in an efficient way. The paper aims to present a research methodology for assessing the maturity of digital education. Hesitant fuzzy linguistic term sets (HFLTS) technique is used to simplify Decision Makers' (DMs) evaluation processes in uncertain circumstances. Hesitant Fuzzy Linguistic (HFL) Decision Making Trial and Evaluation Laboratory (DEMATEL) technique is used to calculate maturity factors' weights and HFL Additive Ratio ASsessment (ARAS) technique is used to rank countries. A case study is realized to illustrate the potential of the methodology. Finally, the concluding remarks and perspectives for future studies are provided.*

Keywords. ARAS, DEMATEL, Digital Education, HFLTS, Maturity, MCDM.

1 Introduction

In order to compete in the digital society, countries are consistently trying to modernize their education systems. The rapid and noticeable digitalization that occurs in daily life has made the need for change in the education and training process to be realized. It is pointed out that the possibilities offered by digitalization in the new society make people's lives more harmonious, sustainable, facilitating, accessible, comfortable and safe in every sense. This is a more comfortable, more accessible learning experience in the amount and time needed in educational environments as in other fields. Beyond the negativities that cause technology to be perceived as a threat, the contribution and benefits it will provide can be possible with the effective digital transformation of education systems in this process (Karoğlu et al., 2020). According to the European Commission's strategy for modernizing education systems, the efficient use of digital learning technologies is an essential element (Kampylis et al., 2015). Therefore, it is important for societies to integrate digital technologies in educational institutions in an efficient way. However, many countries meet challenges about the activities ensuring the digital technology integration, i.e. implementation models (Balaban et al., 2018). In this context, the digital maturity of educational organizations is arising as an important subject. European Commission indicated the significance of digital maturity by offering support throughout its policies and various programs (Ristić, 2017). In the literature, the digital maturity subject for education is examined in different ways for various institutions (Balaban et al., 2018; Ristić, 2017; Harrison et al., 2014; Đurek et al., 2018; Towndrow & Fareed, 2015; Ifenthaler & Egloffstein, 2020).

In this paper, it is aimed to provide a research methodology for assessing the maturity of digital education. The digital maturity of the educational institutions is affected by a number of factors. These factors and their importance can be taken into consideration with the utilization of Multi-Criteria Decision-Making (MCDM) techniques. In this paper, Hesitant Fuzzy Linguistic (HFL) MCDM techniques will be utilized. The importance level of the factors will be determined by implementing the HFL Decision Making Trial and Evaluation Laboratory (DEMATEL) technique. Five countries (a sample of Europe countries) will be ranked with the application of HFL Additive Ratio ASsessment (ARAS) technique.

The fuzzy logic is proposed by Zadeh (1965) for reflecting the uncertainty and vagueness of information. Moreover, the Hesitant Fuzzy Linguistic Term Sets (HFLTS) technique is proposed by Rodriguez et al. (2011) to overcome the hesitation of experts while expressing their opinions. In 2016, HFL DEMATEL method is introduced by Serdarasan et al. (2016) and in 2020, HFL ARAS method is proposed by Büyüközkan & Güler (2020). In this study, HFL DEMATEL-HFL ARAS methodology is integrated for the first time. The findings shows that the most important maturity factor for digital education is

"Interacting and sharing through digital technologies" and the first ranked country is A5.

The paper is organized as follows. The paper is organized as follows. Section 2 presents the methodology and data. Section 3 provides the obtained results, while Section 4 concludes the paper.

2 Research Methodology

The research methodology is presented in Figure 1. which contains three stages.

Step 1: The factors in the maturity model and the alternatives are determined with the help of the literature review and the opinions of the experts.

Step 2: The factors' weights are calculated by implementing HFL DEMATEL method.

Step 3: In the last step, the alternatives are ranked by using HFL ARAS method.

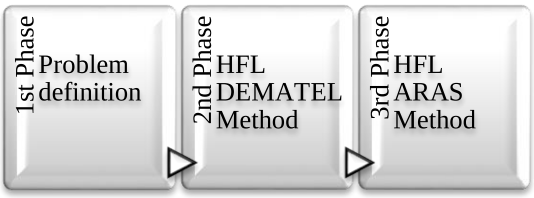

Figure 1. The phases of the research methodology

2.1. Hesitant Fuzzy Linguistic Term Sets

Hesitant Fuzzy Sets (HFS) are first proposed by Torra (2010). HFLTS is introduced by Rodriguez et al. (2011) as a model that represents linguistic expressions by a set of. Please refer to (Torra, 2010; Rodriguez et al., 2011) for further information.

Definition 1: E_{GH} is a function that transforms linguistic phrases into HFLTS. This function is useful for converting comparative linguistic expressions into HFLTS (Rodriguez et al., 2011).

2.2. HFL DEMATEL Method

Step 1. The views of the DMs' are collected. The decision matrix with linguistic statements is constructed and these expressions are converted into HFLTS. Please refer to (Wu et al., 2017) for details.

Step 2. The crisp-direct influence matrix $\bar{A}$ is constructed as:

$$\bar{A} = \begin{bmatrix} \overline{a_{11}} & \cdots & \overline{a_{1n}} \\ \vdots & \ddots & \vdots \\ \overline{a_{n1}} & \cdots & \overline{a_{nn}} \end{bmatrix} \tag{1}$$

Step 3. The elements of the normalized direct-influence matrix B is calculated by using:

$$b_{ij} = \overline{a_{ij}} / \max \sum_{j=1}^{n} \overline{a_{ij}} \tag{2}$$

Step 4. The total-influence matrix is established by using:

$$T = [t_{ij}]_{n\,x\,n} = B(I - B)^{-1} \tag{3}$$

Step 5. The sum of the rows of the matrix T (R_i) and the sum of the columns of the matrix T (C_j) are calculated as:

$$R_i = \sum_{j=1}^{n} t_{ij} \tag{4}$$

$$C_k = \sum_{i=1}^{n} t_{ij} \tag{5}$$

Step 6. The influential weights of the criteria are computed as:

$$w_j = \sqrt{(R_j + C_j)^2 + (R_j - C_j)^2} \tag{6}$$

Then the weights are normalized by using:

$$\overline{w_j} = \frac{w_j}{\sum_{j=1}^{n} w_j} \tag{7}$$

2.3. HFL ARAS Method

Step 1: The decision matrix with linguistic statements is constructed and these expressions are converted into HFLTS. Please refer to (Medineckiene et al., 2015) for details.

Step 2: The matrix is normalized as:

For maxima preferable values of criteria:

$$\tilde{\tilde{x}} = \frac{\widetilde{x_{ij}}}{\sum_{i=0}^{m} \widetilde{x_{ij}}} \tag{8}$$

For minima preferable values of criteria:

$$\widetilde{x_{ij}} = \frac{1}{\widetilde{x_{ij}}^{*}}, \qquad \tilde{\tilde{x}}_{ij} = \frac{\widetilde{x_{ij}}}{\sum_{i=0}^{m} \widetilde{x_{ij}}} \tag{9}$$

Step 3: The weighted normalized matrix is constructed as:

$$\hat{\tilde{x}}_{ij} = \tilde{\tilde{x}}_{ij} \widetilde{w}_j, \ i = 0,1,\ldots,m \tag{10}$$

w_j is the j^{th} criterion's weight and:

$$\sum_{j=1}^{n} w_j = 1 \tag{11}$$

Step 4: The optimality function value of i^{th} alternative is determined as:

$$\widetilde{S}_i = \sum_{j=1}^{n} \hat{\tilde{x}}_{ij}, \ i = 0,1,\ldots,m \tag{12}$$

Step 5: In order to find the result, the center of area technique is applied as:

$$S_i = 1/3(S_{i\alpha} + S_{i\beta} + S_{i\gamma}) \tag{13}$$

Step 6: Alternatives' utility degree is determined as:

$$K_i = \frac{S_i}{S_0}, \ i = 0,1,\ldots,m \tag{14}$$

where S_0 is the value of most ideal criterion.

3 Case Study

As stated in the Opening up Education initiative (European Commission, 2013), educational organizations have to revise their strategies. Their strategies should focus on improving their capacity for implementing digital technologies and digital content (Kampylis et al., 2015). Therefore, it is important to evaluate the digital maturity of educational institutions.

In order to rank the countries according to their digital maturity, different countries are determined and evaluated by using the proposed HFL DEMATEL-HFL ARAS techniques. The maturity factors are summarized in Table 1 and they are based on European Commission's digital maturity model (Eurydice, 2019). Country alternatives are selected grounded on industry reports, academic papers, white papers and the press. The alternatives represents the general situation of educational institutions in those countries. For privacy concerns, the countries are named as A1, A2, A3, A4 and A5.

Table 1. The digital maturity model for education (Eurydice, 2019)

Main Factors	Sub Factors
F1. Information & data literacy	F11. Browsing, searching and filtering data, information and digital content F12. Evaluating data, information and digital content F13. Managing data, information and digital content
F2. Communication & collaboration	F21. Interacting and sharing through digital technologies F22. Collaborating through digital technologies F23. Managing digital identity
F3. Digital content creation	F31. Developing digital content F32. Integrating and re-elaborating digital content F33. Programming
F4. Safety	F41. Protecting devices F42. Protecting personal data and privacy F43. Protecting health and well-being
F5. Problem solving	F51. Solving technical problems F52. Creatively using digital technologies F53. Identifying digital competence gaps

In this study, there are three experts to evaluate the factors and alternatives. All three experts are sufficiently knowledgeable and experienced in the area of education and digitalization. DM1 has experience in research institutions about digital transformation. DM2 is conducting academic and industrial research about digital maturity models. DM3 has public sector experience about digital education. Experts who have insights and experience in education evaluated the maturity factors by using the comparative linguistic terms. These linguistic terms and their triangular fuzzy are provided in Table 2. Table 3 shows the evaluation of main factors.

Table 2. Linguistic terms sets (Beg &Rashid, 2013)

Linguistic term	S_i	Abb.	Fuzzy Numbers
Perfect	s3	P	(0.83,1,1)
Very High	s2	VH	(0.67,0.83,1)
High	s1	H	(0.5,0.67,0.83)
Medium	s0	M	(0.33,0.5,0.67)
Low	s-1	L	(0.17,0.33,0.5)
Very Low	s-2	VL	(0,0.17,0.33)
None	s-3	N	(0,0,0.17)

Table 3. The evaluation matrix for the main factors

Main Factors	F1	F2	F3	F4	F5
F1	Greater than H	Greater than H	Between M and VH	Between M and VH	At least H
F2	At least H	At least H	Greater than H	Greater than H	Between VL and M
F3	Between VL and M	Between M and VH	Greater than H	At least H	At least H
F4	At least H	Between M and VH	At least H	Between VL and M	Greater than H
F5	At least H	Between M and VH	Between VL and M	Between M and VH	Greater than H

The steps of HFL DEMATEL technique Eqs. (1)-(7) are implemented and the maturity factors' weights are found. Table 4 displays the weights.

Table 4. The weights of factors

Main Factors	Weights	Sub Factors	Weights	Ranking
F1	0.211	F11	0.0773	2
		F12	0.0609	13
		F13	0.0725	4
F2	0.207	F21	0.0779	1
		F22	0.0625	11
		F23	0.0661	9
F3	0.194	F31	0.0642	10
		F32	0.0679	6
		F33	0.0624	12
F4	0.192	F41	0.0716	5
		F42	0.0534	15
		F43	0.0671	7
F5	0.196	F51	0.0558	14
		F52	0.0742	3
		F53	0.0661	8

At the end of the HFL DEMATEL application, it is possible to say that the most important digital maturity factor is found as "F21. Interacting and sharing through digital technologies" for educational institutions, followed by "F11. Browsing, searching and filtering data, information and digital content". The third most important factor is found as "F52. Creatively using digital technologies".

Then, experts evaluated countries according to their insights and the reports (Kampylis et al., 2015; Eurydice, 2019; European Union, 2018) by using comparative linguistic terms sets provided in Table 2. The steps of HFL ARAS technique Eqs. (8)-(14) are applied and the ranking of the countries according to their digital maturity is determined. Table 5 displays the results.

Table 5. The ranking of alternatives

Ai	$S_{i\alpha}$	$S_{i\gamma}$	$S_{i\beta}$	*Si*	*Ki*	Ranking
A0	0.201	0.238	0.302	0.247	1.000	-
A1	0.083	0.130	0.204	0.139	0.562	5
A2	0.100	0.155	0.238	0.164	0.664	3
A3	0.107	0.164	0.245	0.172	0.698	2
A4	0.100	0.154	0.237	0.164	0.663	4
A5	0.119	0.179	0.270	0.190	0.767	1

The A5 is ranked as the first among other countries (K1:0.767) and A3 (K3:0.698) is ranked as the second.

To assess the robustness of the HFL ARAS technique, the country alternatives are evaluated with HFL VIKOR and HFL TOPSIS techniques. At the end of these techniques, the similar results are obtained. The most appropriate alternative is found as A5. HFL TOPSIS and HFL VIKOR techniques are distance-based techniques and they are both goal or reference based models. HFL ARAS technique is a relatively new and practical technique. Moreover, ARAS is advantageous with its capability to solve complex problems about contradictory criteria by using simple relative comparisons.

4 Conclusion

The rapid and noticeable digitalization that occurs in daily life has made the need for change in the education and training process to be realized. It is pointed out that the possibilities offered by digitalization in the new society make people's lives more harmonious, sustainable, facilitating, accessible, comfortable and safe in every sense. This is a more comfortable, more accessible learning experience in the amount and time needed in educational environments as in other fields. Beyond the negativities that cause technology to be perceived as a threat, the contribution and benefits it will provide can be possible with the effective digital transformation of education systems in this process (Karoğlu et al., 2020). The training of manpower who will design, develop and produce technology in every field according to the requirements of the fourth industrial revolution is an inevitable reality. Young minds should be given education and training that meets the requirements of the fourth industrial revolution (Demir, 2018).

Digital technologies have an progressively vital role in driving educational innovation. Several strategies at local, regional, national and international levels are encouraging digital education. Therefore, in this paper, it was aimed to provide a research methodology for assessing the maturity of digital education. In this context, an integrated HFL DEMATEL-HFL ARAS methodology is implemented. This paper contributes to the literature by integrating these techniques for the first time. At the end of the implementation, the most important maturity factor for digital education is found as “Interacting and sharing through digital technologies”. The role of institutions and teachers who will take part in this process is very important in the realization of digital transformation in education. It is essential that teachers are aware of the transformation in education from the first years of education, and that they are trained in harmony with this process and that plans are made for this. In order to ensure effective learning today, teacher candidates should benefit from communication studies, human power and non-human power resources. In order for teacher candidates to adapt to technological processes, the educational management organization should systematically plan, implement, evaluate and develop their learning processes.

In future studies, it can be interesting to extend our analysis by implementing HFL aggregation operators (ordered weighted hesitant fuzzy weighted averaging (OWHFWA) operator, the ordered weighted hesitant fuzzy weighted geometric (OWHFWG) operator, the ordered weighted generalized hesitant fuzzy weighted averaging (OWGHFWA) operator etc.) in group decision making approach. For the future research, the number of the digital maturity model factors for education can be increased.

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